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(NASA-CR-124090) SUMMARY OF RESULTS OF PARAMETRIC STUDIES OF SPACE SHUTTLE BOOSTER, ORBITER, AND LAUNCH VEHICLE CONCEPTS Final (Lockheed Missiles and Space Co.) 168 p HC $10.50 CSCL 22B G3/31

N73-18862

Unclas 17158

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HUNTSVILLE, ALABAMA

168

HREC-6370-2
LMSC-HREC TR D306346

LOCKHEED MISSILES & SPACE COMPANY, INC.
HUNTSVILLE RESEARCH & ENGINEERING CENTER
HUNTSVILLE RESEARCH PARK
4800 BRADFORD DRIVE, HUNTSVILLE, ALABAMA

SUMMARY OF RESULTS OF PARAMETRIC STUDIES OF SPACE SHUTTLE BOOSTER, ORBITER, AND LAUNCH VEHICLE CONCEPTS

31 December 1972

Contract NAS8-26370

Prepared for National Aeronautics and Space Administration
Marshall Space Flight Center, Alabama 35812

by

Dale Bradley
Robert E. Buchholz

APPROVED: B. Hobson Shirley
B. Hobson Shirley, Supervisor
Aerophysics Section

J. S. Farrior
J.S. Farrior
Resident Director

FOREWORD

This report presents the results of analytical and experimental space shuttle aerodynamic studies conducted by the Lockheed Missiles & Space Company, Inc., Huntsville Research & Engineering Center (Lockheed-Huntsville), while under contract from the Aero-Astrodynamics Laboratory of the George C. Marshall Space Flight Center (Contract NAS8-26370). The experimental results presented in this report were obtained in tests conducted between 15 June 1971 to 31 December 1972. These studies were conducted by the Aerodynamic Design Group of the Aerophysics Section of Lockheed-Huntsville. This report has been prepared in response to the requirement of the subject contract for a final summary report. The NASA Technical Monitor of this contract is Mr. Paul E. Ramsey, S&E-AERO-AAE.

ACKNOWLEDGEMENT

The authors are grateful to Roger R. Ellis, James A. Moore, Robert A. Lott, Douglas J. Elder and Mickey D. Gamble, all of Lockheed-Huntsville, who made substantial contributions to this analytical/experimental study.

SUMMARY

The results of analytical and experimental parametric studies of space shuttle booster, orbiter and launch vehicle aerodynamics are described for the period 15 June 1971 through 31 December 1972. Results of studies conducted from 1 July 1970 to 15 June 1971 have been previously reported in an interim report. These studies were conducted by the Aerodynamic Design Group, Aerophysics Section of Lockheed-Huntsville while under contract to NASA-George C. Marshall Space Flight Center, Contract NAS8-26370. During this study over 1700 hours of experimental wind tunnel tests were conducted by Lockheed on several versions of the shuttle booster, orbiter and launch vehicle. Fifteen separate tests were conducted in three different test facilities. Test data were published by NASA-MSFC through a separate contract with Chrysler. The test data documents are referenced later in this report. Due to the number of test programs conducted and the time required for test preparation, analysis of the test data has been limited to that required to drive the experimental program. No documentation of the data analysis has been published nor will it be included in this report. A brief description of each of the experimental tests conducted including the test purpose and approach is included in this report. Several test models were designed and fabricated by Lockheed for NASA-MSFC in support of the experimental program. These models are described in this report in the sections which relate to a specific test program.

CONTENTS

LIST OF ILLUSTRATIONS

NOMENCLATURE

Symbol	Definition
CND POS	canard position for flyback booster; 1 is high position, 2 is low position
i	incidence angle, deg
ℓ	length, in.
$\dot{m}$	mass flow rate, lb-mass per second
S	surface area, in^2
STK LOC	strake location for solid rocket motor, deg, left side of body is zero position
WNG POS	wing position for flyback booster; 1 is high position, 2 is low position
X	longitudinal position, in.
Y	lateral position, in.
Z	vertical position, in.
Greek	
α	angle of attack, deg
β	angle of sideslip, deg
Γ	dihedral angle, deg
δ	control surface deflection, deg
θ	semivertex angle, deg
ϕ	roll angle or in the case of solid rocket motors in the launch configuration, their position relative to the HO tank, 0 being at the top of the tank, deg

Subscripts

a	aileron
b	base
c	canard
CY	cylinder
e	elevon
F	flap or flare
L	left
NOZ	nozzle
ORB	orbiter
R	right
r	rudder
SRM	solid rocket motor
STK	strake
T	tail
w	wing

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In reply refer to:
LMSC-HREC D306412
18 January 1973

National Aeronautics and Space Administration
George C. Marshall Space Flight Center
Marshall Space Flight Center, Alabama 35812

Attention: A&TS-PR-M

Subject: Contract NAS8-26370, Submittal of Summary Report

Gentlemen:

Enclosed is the Summary Report as required under the subject contract.

Very truly yours,

LOCKHEED MISSILES & SPACE COMPANY, Inc.

J. E. Eckert, Contracts
Huntsville Research & Engineering Center

JEE:pgp

Encl: LMSC-HREC TR D306346, HREC-6370-2, "Summary of Results of Parametric Studies of Space Shuttle Booster, Orbiter, and Launch Vehicle Concepts," Summary Report, Contract NAS8-26370.

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Section 1
INTRODUCTION

The NASA-George C. Marshall Space Flight Center (MSFC) is currently conducting extensive technology studies to support the aerodynamic development of a space shuttle system. The Aerodynamic Design Group, Aerophysics Section, of Lockheed-Huntsville is under contract to provide assistance to MSFC in these studies. Lockheed-Huntsville overall objectives are: (1) plan and conduct analytical studies of booster and orbiter geometry as an aid in specifying the parameters to be studied experimentally; (2) provide liaison between MSFC and contractors during the design and manufacture of test models; (3) plan, conduct and coordinate experimental wind tunnel tests of the booster, orbiter and launch vehicles in the test facilities which will be provided by MSFC; and (4) analyze and document results of all studies. The Lockheed-Huntsville support began in July 1970 when the original contract was awarded and was continued by an extension in April 1971 and another in January of 1971. The initial study was based on completely reusable flyback booster and orbiter configurations (MSFC delta-wing booster and MDAC model 256-14 orbiter). Lockheed provided assistance in the design of the models, in planning the experimental test programs, and conducting the tests. Results of studies conducted between 1 July 1970 and 15 June 1971 have been reported previously in Ref. 1.

- Booster Studies

The progression of the test program and overall summary of this study is presented in Chart 1. Tests of the booster model were conducted in the 7 x 10-foot transonic wind tunnel at the Naval Ship Research & Development Center (NSRDC) and in the 8 x 8-foot transonic wind tunnel at Cornell Aeronautical Laboratory (CAL) (Refs. 2 through 5). The flyback booster static stability and control characteristics were measured for variations in geometry

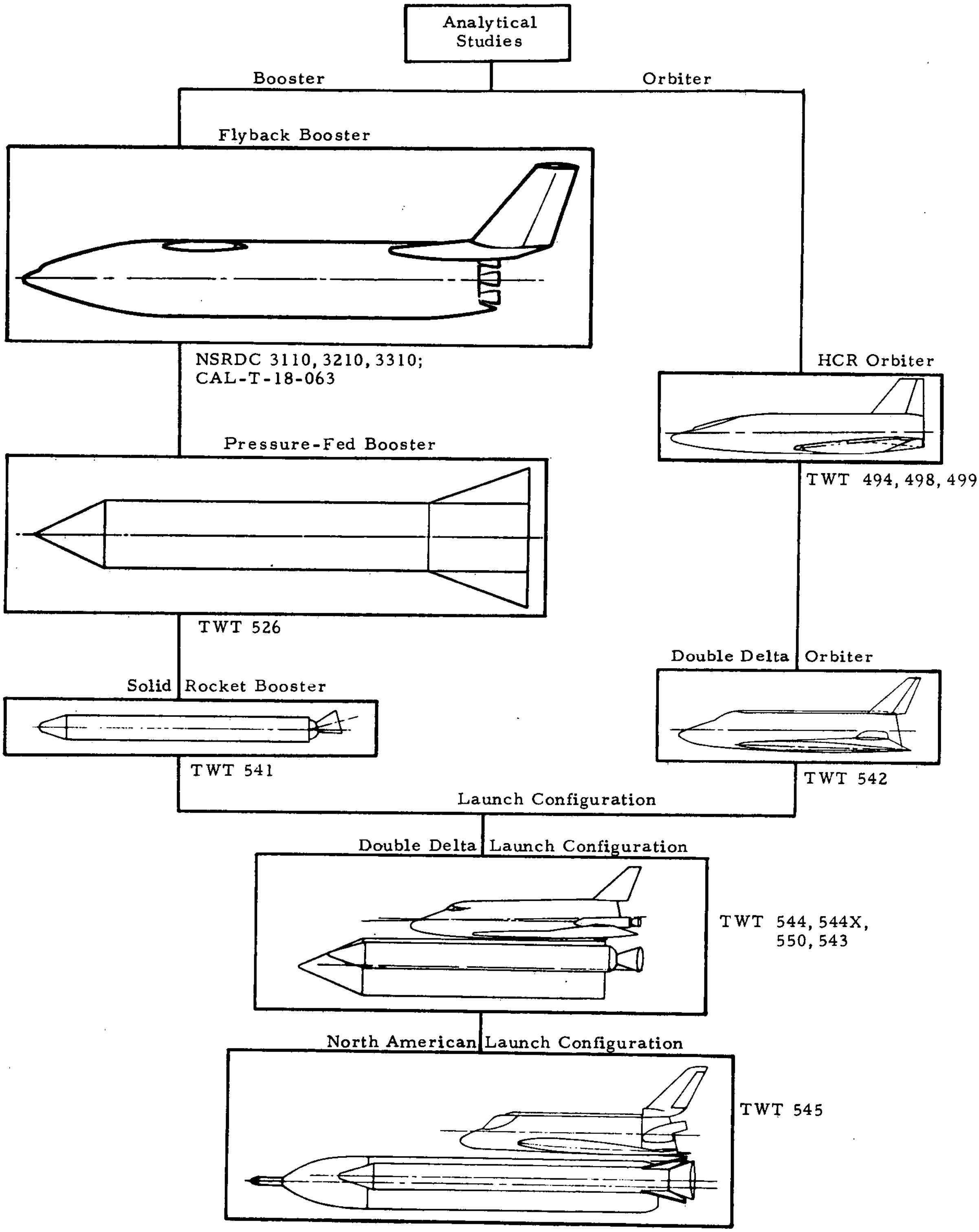

Chart 1 - Evolution of Experimental Tests for Contract NAS8-26370 Showing Relative Sizes of Vehicles

such as high and low wing and canard positions, wing and canard exposed area, vertical surface size and location of cruise engines. A cold flow non-metric engine simulation test was conducted to measure the interference effects of the cruise engine exhaust on the booster aerodynamics including control effectiveness. A short test was also conducted to determine possible techniques for reducing the large base drag of such a blunt based configuration (Ref. 5). Shortly after the completion of these booster tests (November 1971) the decision was made by NASA to drop the flyback concept in favor of water recoverable boosters. A parametric water recoverable booster model was then tested (Ref. 6, February 1972) to determine the high angle of attack (50 deg $\leq \alpha \leq$ 90 deg) aerodynamic characteristics of such a concept. Included in the geometrical parameters of the cone-cylinder-frustum-fin concept were: cone angle, cylinder length, frustum angle and fin exposed area. Results from this test were to be used by MSFC in preliminary design efforts. The last booster alone test conducted under this study (Ref. 7, May 1972) was to obtain data on a solid rocket booster design at very large angles of attack (-10 deg $\leq \alpha \leq$ 190 deg), to simulate all possible reentry attitudes.

- Orbiter Studies

Tests of the MDAC model 256-14 orbiter began in June 1971 (Ref. 8) but this configuration was abandoned by MSFC in favor of a more parametric symmetrical airfoil model. Lockheed aided MSFC in the preliminary design of the new model with results of analytical studies. Tests of the new orbiter configuration were conducted in August 1971 to determine the static stability and control effectiveness and the effects of wing tip fins, a center dorsal fin, wing exposed area and aspect ratio, and elevon exposed area (Ref. 8). Soon after these tests were completed NASA abandoned the large reusable orbiter in favor of an external fuel tank configuration which required a much smaller orbiter. In support of the development of the new orbiter Lockheed designed and fabricated a 0.004-scale model and tested it to determine the static stability and control characteristics (Ref. 9). This test was conpleted in May 1972. In late August 1972 Lockheed was directed by MSFC to design and fabricate a

0.004-scale model of the North American Rockwell (NAR) orbiter. This task was completed by Lockheed and the model was tested by the MSFC COR (Mr. Ramsey) during September 1972. An additional test was planned by Lockheed to determine orbiter wing panel loads (Ref. 10) but was cancelled by MSFC.

- Launch Vehicle

Launch vehicle tests (Ref. 11) began in May 1972 to determine the aerodynamic characteristics of the launch configuration and to study the effect of: orbiter incidence relative to the external fuel tank (HO tank) and solid rocket motors (SRMs); SRM longitudinal and radial location on the HO tank; and orbiter-HO tank separation distance. Orbiter wing panel and body centerline pressures were measured while mounted on the launch vehicle in a test conducted in July 1972. Orbiter incidence angle, SRM radial location on the HO tank and HO tank nose shape were varied during the test. The pressure distributions over the HO tank and SRMs when mounted with the orbiter as the launch configuration were obtained in a test conducted during August and September 1972 (Ref. 12). Models for this test program were designed and fabricated by Lockheed from Emerson and Cumings Stycast material. The final test conducted under this contract was a launch vehicle test to determine the mutual interference effects of the orbiter, the HO tank and the SRMs (Refs. 13 and 14). The orbiter, HO tank and SRMs were all mounted on separate stings in order that all mutual interference effects could be determined.

- Analysis of Test Data

Analysis of the test data obtained during this study was limited to that required to drive the experimental program. It should also be mentioned that several of the tests conducted were of a very general nature and are worthy of detailed analysis. Such analysis was not possible under this contract because of the rapid response required to keep pace with the shuttle development. Data analysis reports were published by Lockheed concerning the analytical trade studies of a LOX-RP booster concept (Ref. 15) and when it was deemed necessary to document possible sources of data anomalies (Refs. 16 and 17).

Section 2
DESCRIPTION OF EXPERIMENTAL STUDIES

A chronological listing of the experimental tests conducted during this study is included as Table 1. These tests, the test models and test facilities are described in the following sub-sections. For each test the test purpose, data reduction and a brief discussion of the test operation are presented.

Table 1

EXPERIMENTAL TEST PROGRAMS CONDUCTED UNDER CONTRACT NAS8-26370

Test	Test Date	Purpose	Occupancy Hours	SADSAC Report	Pretest Report (LMSC-HREC-)
NSRDC3110	3-71	Parametric Flyback Booster	260	119,995	D162856
NSRDC3210	4-71	Flyback booster cruise engine location and power-on effects	88	120,005	D162968
TWT494	6-71	Baseline(1) modified MDAC orbiter parametric test	102	120,000	D225042
TWT498	8-71	MDAC modified orbiters 2A and 2B parametric. Also run as a check on tunnel blockage. Used NAR sting, and had a P_o comparison	152	120,020	D225042-A
TWT499	8-71	MDAC modified orbiter 2A. Used MSFC and Lockheed stings to check blockage	75	No SADSAC report published	D255042-A
NSRDC3310	8-71	Flyback booster lateral-directional and cruise engine location studies	56	120,019	D255297
CAL-T-18-063	11-71	Flyback booster base drag reduction	28	120,030	D255393
TWT526	2-72	Parametric pressure-fed booster	154	120,042	D255623
TWT541	5-72	156-inch solid rocket motor reentry	140	120,056	D225833
TWT542	5-72	Parametric double delta orbiter	58	120,057	D225857
TWT544	5-72	Double delta orbiter parametric launch vehicle	131	120,059	D225929
TWT550	7-72	Double delta orbiter wing pressure test in launch configuration	69	120,075	D306060
TWT544X	7-72	Double delta orbiter parametric launch vehicle (extension)	116	120,074	D306029
TWT543	9-72	Pressure distribution on HO tank and SRMs while in the double delta orbiter launch configuration	132	120,058	D306027
TWT545	10-72	Dual balance mutual interference test for NAR launch configuration	223	120,060	D306153 D306153-A

2.1 PARAMETRIC STUDY OF A 0.00325-SCALE ORBITER MODEL (TWT 498 and TWT 499)

This test was an extension of the Space Shuttle orbiter tests performed during the first phase of this contract. The orbiter body was identical to the orbiter model previously tested (Model 1) but the wing was of higher aspect ratio. The model had provision for either tip fins or a center dorsal fin. Data from this test were to be compared with Model 1 data to provide a basis for optimization of orbiter performance and stability and control. The test was conducted at Mach numbers ranging from 0.6 to 4.96, angles of attack from -4 to +50 degrees and angles of side slip from -9 to +9 degrees at angles of attack of 0,10 and 15 degrees. A pretest report for this test was published in April 1971 (Ref. 8).

2.1.2 Test Facility

A complete description of the MSFC 14 x 14-Inch Trisonic Wind Tunnel is presented in Ref. 18 from which the following excerpts were taken:

> "The tunnel is an intermittent trisonic blowdown tunnel operated from pressure storage to vacuum or atmospheric exhaust. The test section measures 14 x 14 inches in two of the interchangeable test sections. The transonic section provides for Mach numbers of 0.20 through 2.50 and the supersonic section provides for Mach 2.75 through 5.00.
>
> "Air is supplied to a 6000 cubic foot storage tank at -40°F dew point and 500 psia. The compressor is a three-stage reciprocating unit driven by a 1500 hp motor.
>
> "The tunnel flow is established with a servo-controlled gate valve. Air from the control valve flows through the valve diffuser into the stilling chamber where the air can be heated up to 200°F. Air then flows into the test section which contains the nozzle blocks and test area.
>
> "Speeds are varied in the subsonic range by a controllable diffuser, in the transonic range by perforated tunnel walls, in the low (1.5 to 2.5) supersonic range by tilting fixed contour nozzle blocks.
>
> "The transonic section has variable porosity walls that allow for optimum wave cancellation in the transonic flow region.

"Downstream of the test section is a hydraulically controlled sector that provides for angles of attack of ±10 degrees with various offsets extending the pitch limits to 90 degrees.

"The variable diffuser, with its movable floor and ceiling panels, is the primary means for controlling the subsonic speeds; it also allows for more efficient supersonic runs. The sector assembly and diffuser telescope to allow easy access to the model and test section.

"The tunnel flow is then exhausted through an acoustically damped tower to atmosphere or into the vacuum field of 42,000 cubic feet. The tanks are evacuated by five vacuum pumps driven by a total of 500 hp.

"Data are recorded by a solid state digital data acquisition system. The digital data are transferred to punched cards during the run to be reduced later to proper coefficient form by a computer."

Fig. 1 shows a cross section of the tunnel.

2.1.3 Model Description

The model tested was a 0.00325-scale modified version of a McDonnell-Douglas Space Shuttle orbiter. The body was identical to the unmodified configuration, but the wing was of higher aspect ratio (Æ = 2.0 for the no tip fin case, 2A) and contained no twist or camber. The model was tested in two forms, with straight wing tips and centerline dorsal fin (Model 2A) and with wingtip fins (Model 2B). The elevons and rudders are capable of being deflected to provide control effectiveness data. Sketches of the models are shown in Figs. 2a and 2b.

Model nomenclature for the various model components is listed below:

Symbol	Definition
B2	model 2A and 2B body
D1	dorsal fin (S_e = 900.3 ft^2)
D2	dorsal fin (S_e = 722.1 ft^2)
e3	model 2A elevon
e4	model 2B elevon
r1	rudder-dorsal D1
r2	rudder-dorsal D2

r4	rudder-tip fin V2
V2	tip fin-wing W5 (S_e = 632.4 ft^2)
V4	tip extension-wing W2 (S_e = 240 ft^2 ea)
W2	model 2A wing (S_e = 3963 ft^2)
W5	model 2B wing-w/o tip fins (S_e = 3468 ft^2)

All model parts are shown in Fig. 3.

Figure 4 shows the model installed in the tunnel. The model is fabricated of 17-4 PH stainless steel. Model design and construction was performed by the Naval Ship Research and Development Center, Carderock, Maryland.

2.1.4 Data Reduction

Model forces and moments were measured by MSFC balances 201 and 231. All forces and moments were reduced to nondimensional coefficients. Reference dimensions used for data reduction are listed in Table 2. Data were corrected for weight tares and sting deflections. The data for TWT 498 were entered into the Chrysler Corporation's System for Analysis and Development of Static Aerothermodynamic Criteria (SADSAC) and published as a data report (Ref. 19). TWT 499 test data were not published because of possible data discrepancies due to blockage and sting interference.

2.1.5 Discussion

An outline of the configurations tested is shown in Table 3a for TWT 498 and Table 3b for TWT 499. The parametric portions of this test were run first. During the parametric investigation, anomalies in the data were discovered. To investigate these anomalies the test was extended and various stings were tested with the basic model to determine the effects of sting interference and tunnel blockage. The results of these studies are published in Refs. 16 and 17. The combined tests required 227 wind tunnel occupancy hours to complete.

Table 2

0.00325-SCALE HCR ORBITER REFERENCE DIMENSIONS

Parameter	Full Scale	Model Scale
Reference Area (S_{ref})	5935 ft^2	0.063 ft^2 (9.025 in^2)
Reference Length (ℓ_{ref}, b)		
Models 1, 2A and 2B	157.487 ft	0.512 ft (6.142 in.)
Balance Location (BMC)		
Models 1, 2A and 2B (from nose)	—	0.352 ft (4.222 in.)
Moment Reference Center		
Models 1, 2A and 2B (from nose)	102.367 ft	0.333 ft (3.996 in.)
(above model ℄)	0.0	0.0
Base Area (A_b)		
Model 1 (baseline)	362.50 ft^2	0.004 ft^2 (0.551 in^2)
Models 2A and 2B	303.20 ft^2	0.003 ft^2 (0.461 in^2)

Table 3a

RUN SCHEDULE FOR TWT 498

DATA SET IDENTIFIER	CONFIGURATION	SCHD.		PARAMETERS/VALUES				NO. of RUNS	MACH NUMBERS (OR ALTERNATE INDEPENDENT VARIABLE)											
		α	β	δ_{e_3}	δ_{r_1}	δ_{r_2}	δ_{r_4}		δ_{a_L}	δ_{a_R}		0.6	0.7	0.9	1.1	1.3	1.46	1.96	4.96	
	B2W2V4D2e3r2	A	0	0°	—	0°	—		0°	0°		✓	✓	✓	✓		✓	✓	✓	
		B										✓	✓	✓	✓		✓	✓	✓	
		C										✓	✓		✓	✓	✓	✓	✓	
		D													✓	✓		✓	✓	
		0	X									✓	✓	✓	✓		✓	✓	✓	
		10										✓	✓	✓	✓		✓	✓	✓	
		15										✓	✓	✓	✓		✓	✓	✓	
		A	0	+10°								✓		✓	✓			✓	✓	
		B		+10°								✓		✓				✓	✓	
		A		-10°								✓		✓	✓			✓	✓	
		B										✓		✓				✓	✓	
		C																✓	✓	
		D																✓	✓	
		A		-20°								✓		✓	✓			✓	✓	
		B										✓		✓				✓	✓	
		C																✓	✓	
		D																✓	✓	
		A		-30°								✓		✓				✓	✓	
		B		-30°								✓		✓				✓	✓	
		A		0					-10°	+10°		✓		✓				✓	✓	

1 7 13 19 25 31 37 43 49 55 61 67 75 76

COEFFICIENTS: → IDPVAR(1) | IDPVAR(2) | NDV

α or β SCHEDULES

α: A = −4° to 10° by Δα = 2°; B = 6°, 8°, 10°, 12°, 14°, 15°, 17°, 19°, 21°, 23°, 25°

α: C = 20° to 40° by Δα = 2°; D = 40° to 60° by Δα = 2°

β: X = −4° to 10° by Δβ = 2° or −9° to 9° by Δβ = 3°

Table 3a (Continued)

DATA SET IDENTIFIER	CONFIGURATION	SCHD. α	SCHD. β	PARAMETERS/VALUES δ_{e3}	δ_{r1}	δ_{r2}	δ_{r4}	NO. of RUNS	MACH NUMBERS (OR ALTERNATE INDEPENDENT VARIABLE) δ_{aL}	δ_{aR}		0.6	0.7	0.9	1.1	1.46	1.96	4.96		
	B2W2V4D2e3r2	B	0	0°	—	0°	—		-10°	+10°		✓		✓			✓	✓		
		A							-20°	+20°		✓		✓			✓	✓		
		B							-20°			✓		✓			✓	✓		
		A		+10°					0°			✓		✓			✓	✓		
		B							0°									✓		
		A							-10°	+30°		✓		✓			✓	✓		
		B							-10°	+30°		✓		✓			✓	✓		
		A		-10°					-20°	0°		✓		✓			✓	✓		
		B							-20°	0°								✓		
		A							-30°	+10°		✓		✓			✓	✓		
		B							-30°	+10°		✓		✓			✓	✓		
		0	X	0°		+10°			0°	0°		✓		✓	✓		✓	✓		
		10																✓		
		15										✓		✓	✓		✓	✓		
		0				+20°						✓		✓	✓		✓	✓		
		10																✓		
		15			0°													✓		
	B2W2V4D1e3r1	0				—						✓		✓	✓		✓	✓		
		10										✓		✓	✓		✓	✓		
		15										✓		✓	✓		✓	✓		

1 7 13 19 25 31 37 43 49 55 61 67 75 76

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Table 3a (Continued)

DATA SET IDENTIFIER	CONFIGURATION	SCHD. α	SCHD. β	PARAMETERS/VALUES δ_{e3}	δ_{r1}	δ_{r2}	δ_{r4}	NO. of RUNS	MACH NUMBERS (OR ALTERNATE INDEPENDENT VARIABLE) δ_{aL}	δ_{aR}		0.6	0.7	0.9	1.1	1.46	1.96	4.96		
	B2W2V4D1e3r1	0	X	0°	+10°	—	—		0°	0°		✓		✓	✓		✓	✓		
	↓	10	↓	↓	+10°	↓	↓		↓	↓								✓		
	B2W2V4 e3	0	↓		—	↓						✓		✓	✓	✓	✓	✓		
	B2W2V4 D2e3r2	G	0		↓	0°									✓					
	↓	G	0	↓	↓	0°	↓		↓	↓					✓					
	CONFIGURATION	α	β	δ_{e4}	δ_{r1}	δ_{r2}	δ_{r4}		δ_{aL}	δ_{aR}		0.6	0.7	0.9	1.1	1.46	1.96	4.96		
	B2W5V2e4r4	A	0	0°	—	—	0°		0°	0°		✓	✓	✓	✓	✓	✓	✓		
		B										✓	✓	✓	✓	✓	✓	✓		
		C										✓	✓	✓	✓	✓	✓	✓		
		D	↓														✓	✓		
		0	X									✓	✓	✓	✓	✓	✓	✓		
		10										✓	✓	✓	✓	✓	✓	✓		
		15	↓	↓								✓	✓	✓	✓	✓	✓	✓		
		A	0	+10°								✓		✓	✓		✓	✓		
		B		+10°								✓		✓			✓	✓		
		A		-10°								✓		✓	✓		✓	✓		
		B										✓		✓			✓	✓		
		C															✓	✓		
		D		↓													✓	✓		
	↓	A	↓	-20°	↓	↓	↓		↓	↓		✓		✓	✓		✓	✓		

1 7 13 19 25 31 37 43 49 55 61 67 75 76

IDPVAR(1) | IDPVAR(2) | NDV

COEFFICIENTS:

α or β SCHEDULES

α: A = -4° to 10° by Δα = 2°; B = 6°, 8°, 10°, 12°, 14°, 15°, 17°, 19°, 21°, 23°, 25°; C = 20° to 40° by Δα = 2°

D = 40° to 60° by Δα = 2°; G = 10° to 30° by Δα = 2°

β: X = -4° to 10° by Δβ = 2° or -9° to 9° by Δα = 3°

Table 3a (Continued)

DATA SET IDENTIFIER	CONFIGURATION	SCHD. α	SCHD. β	PARAMETERS/VALUES δ_{e4}	δ_{r1}	δ_{r2}	δ_{r4}	NO. of RUNS	MACH NUMBERS (OR ALTERNATE INDEPENDENT VARIABLE) δ_{aL}	δ_{aR}		0.6	0.7	0.9	1.1	1.46	1.96	4.96		
	B2W5V2e4r4	B	0	-20°	—	—	0°		0°	0°		✓		✓			✓	✓		
		C															✓	✓		
		D															✓	✓		
		A		-30°								✓		✓			✓	✓		
		B		-30°								✓		✓			✓	✓		
		A		0°					-10°	+10°		✓		✓			✓	✓		
		B							-10°	+10°		✓		✓			✓	✓		
		A							-20°	+20°		✓		✓			✓	✓		
		B							-20°			✓		✓			✓	✓		
		A		+10°					0°			✓		✓			✓	✓		
		B							0°									✓		
		A							-10°	+30°		✓		✓			✓	✓		
		B							-10°	+30°		✓		✓			✓	✓		
		A		-10°					-20°	0°		✓		✓			✓	✓		
		B							-20°	0°								✓		
		A							-30°	+10°		✓		✓			✓	✓		
		B							-30°	+10°		✓		✓			✓	✓		
		0	X	0°			+10°		0°	0°		✓		✓	✓		✓	✓		
		10																✓		
		15										✓		✓	✓		✓	✓		

1 7 13 19 25 31 37 43 49 55 61 67 75 76

COEFFICIENTS: → IDPVAR(1) | IDPVAR(2) | NDV

α or β SCHEDULES

α: A = -4° to 10° by Δα = 2°; B = 6°, 8°, 10°, 12°, 14°, 15°, 17°, 19°, 21°, 23°, 25°;
C = 20° to 40° by Δα = 2°; D = 40° to 60° by Δα = 2°

β: X = -4° to 10° by Δβ = 2° or -9° to 9° by Δβ = 3°

Table 3a (Concluded)

DATA SET IDENTIFIER	CONFIGURATION	SCHD.		PARAMETERS/VALUES				NO. of RUNS	MACH NUMBERS (OR ALTERNATE INDEPENDENT VARIABLE)											
		α	β	δ_{e4}	δ_{r1}	δ_{r2}	δ_{r4}		δ_{aL}	δ_{aR}		0.6	0.7	0.9	1.1	1.46	1.96	4.96		
	B2W5V2e4r4	0	X	0°	—	—	+20°		0°	0°		✓		✓	✓		✓	✓		
	↓	10	↓	↓	↓	↓	↓		↓	↓								✓		
	↓	15	↓	↓	↓	↓	↓		↓	↓								✓		
	B2W5V2D2e4r4r2	B	0	↓	↓	↓	0°		-20°	+20°		✓		✓						

1 7 13 19 25 31 37 43 49 55 61 67 75 76

COEFFICIENTS: → IDPVAR(1) | IDPVAR(2) | NDV

α or β SCHEDULES

α: B = 6°, 8°, 10°, 12°, 14°, 15°, 17°, 19°, 21°, 23°, 25°

β: X = -4° to 10° by Δβ = 2° or -9° to 9° by Δβ = 3°

Table 3b

RUN SCHEDULE FOR TWT 499

DATA SET IDENTIFIER	CONFIGURATION	SCHD. α	SCHD. β	PARAMETERS/VALUES δ_{e3}	δ_{r2}	δ_{aL}	δ_{aR}	NO. of RUNS	MACH NUMBERS (OR ALTERNATE INDEPENDENT VARIABLE) δ_{e1}		0.6	0.7	0.9	1.1	1.46	1.96	4.96			
	B2W2V4D2e3r2	E	0	0°	0°	0°	0°		—		✓	✓	✓	✓	✓	✓	✓			
	↓	0	X	0°	↓	↓	↓		↓		✓	✓	✓	✓	✓	✓	✓			
	↓	E	0	+10°	↓	↓	↓		↓		✓		✓	✓		✓	✓			
	↓	↓	↓	-10°	↓	↓	↓		↓		✓		✓	✓		✓	✓			
	↓	↓	↓	0°	↓	-10°	+10°		↓		✓		✓			✓	✓			
	↓	0	X	0°	+10°	0°	0°		↓		✓		✓	✓		✓	✓			
	B1W1V1e1	E	0	—	—	↓	↓		0°		✓		✓							
	B2W2V4D2e3r2	F	↓	0°	0°	↓	↓		—		✓	✓	✓	✓	✓	✓	✓			
	↓	G	↓	↓	↓	↓	↓		↓		✓	✓	✓	✓	✓	✓	✓			
	↓	H	↓	↓	↓	↓	↓		↓					✓		✓	✓			
	↓	0	X	↓	↓	↓	↓		↓		✓	✓	✓	✓	✓	✓	✓			
	↓	F	0	+10°	↓	↓	↓		↓		✓		✓	✓		✓	✓			
	↓	G	↓	+10°	↓	↓	↓		↓		✓		✓			✓	✓			
	↓	F	↓	-10°	↓	↓	↓		↓		✓		✓	✓		✓	✓			
	↓	G	↓	↓	↓	↓	↓		↓		✓		✓			✓	✓			
	↓	H	↓	↓	↓	↓	↓		↓							✓	✓			
	↓	F	↓	0°	↓	-10°	+10°		↓		✓		✓			✓	✓			
	↓	G	↓	↓	↓	-10°	+10°		↓		✓		✓			✓	✓			
	↓	0	X	↓	+10°	0°	0°		↓		✓		✓	✓		✓	✓			

1 7 13 19 25 31 37 43 49 55 61 67 75 76

COEFFICIENTS: → IDPVAR(1) | IDPVAR(2) | NDV

α or β SCHEDULES

α: E = -4° to 14° by Δα = 2°; F = -4° to 10° by Δα = 2°; G = 10° to 30° by Δα = 2°

H = 30°, 34°, 38°, 40°, 42°, 46°, 50°

β: X = -4° to ~~16~~ by Δβ = 2°

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Table 3b (Concluded)

DATA SET IDENTIFIER	CONFIGURATION	SCHD. α	SCHD. β	PARAMETERS/VALUES δ_{e3}	δ_{r2}	δ_{aL}	δ_{aR}	NO. of RUNS	MACH NUMBERS (OR ALTERNATE INDEPENDENT VARIABLE)	0.6	0.7	0.9	1.1	1.46	1.96	4.96				
	B2W2V402e3r2	E	O	0°	0°	0°	0°			✓	✓	✓	✓	✓	✓	✓				
	↓	O	X	0°	↓	↓	↓			✓	✓	✓	✓	✓	✓	✓				
		E	O	+10°						✓		✓	✓		✓	✓				
		↓	↓	-10°						✓		✓	✓		✓	✓				
				0°		-10°	+10°			✓		✓			✓	✓				
		O	X	0°	+10°	0°	0			✓		✓	✓		✓	✓				

17

1 7 13 19 25 31 37 43 49 55 61 67 75 76

COEFFICIENTS: → IDPVAR(1) | IDPVAR(2) | NDV

α or β SCHEDULES

α: E = -4° to 14° by Δα = 2°

β: X = -4° to 16° by Δβ = 2°

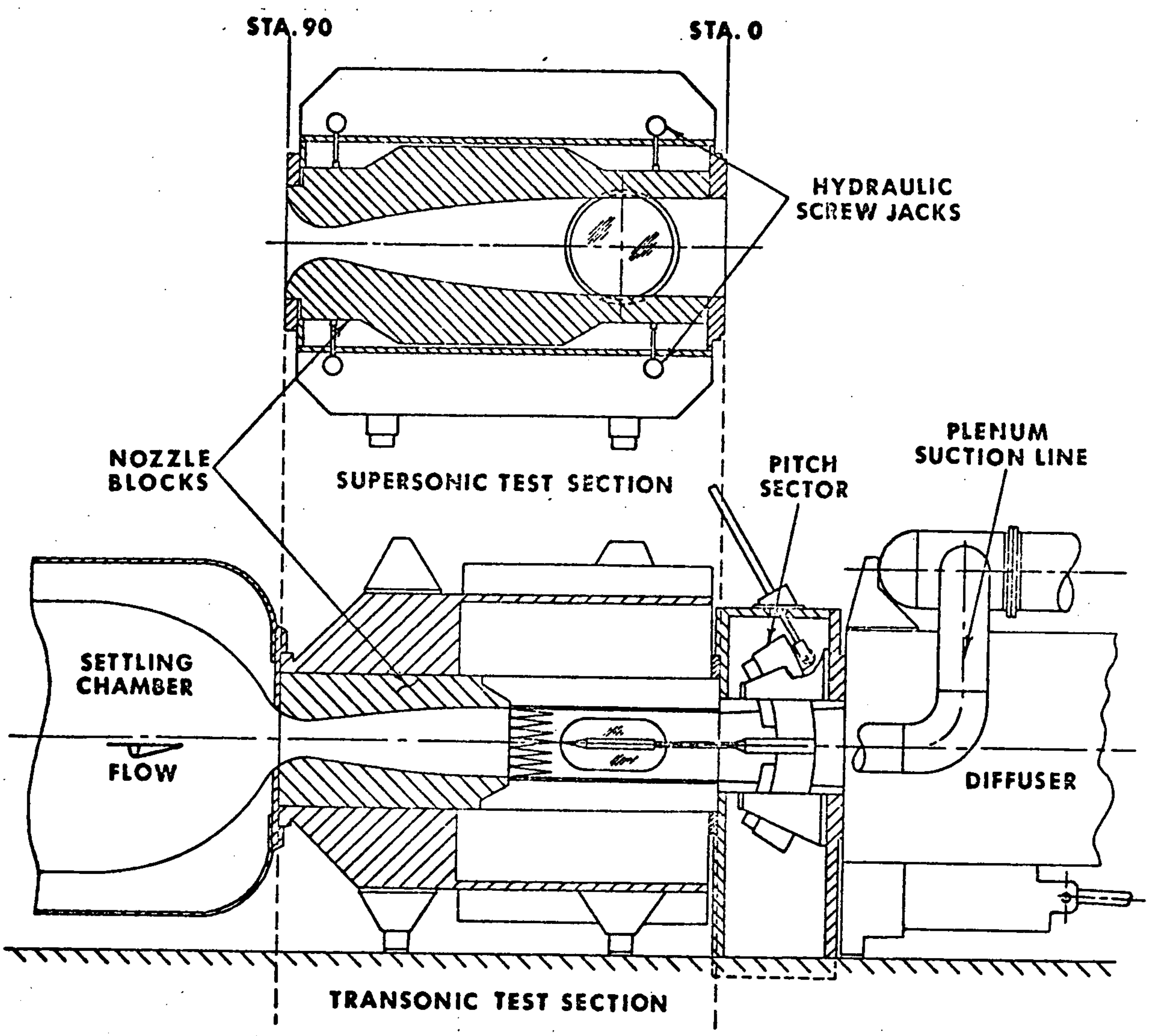

Fig. 1 - Cross Section of the MSFC 14 x 14-Inch Trisonic Wind Tunnel

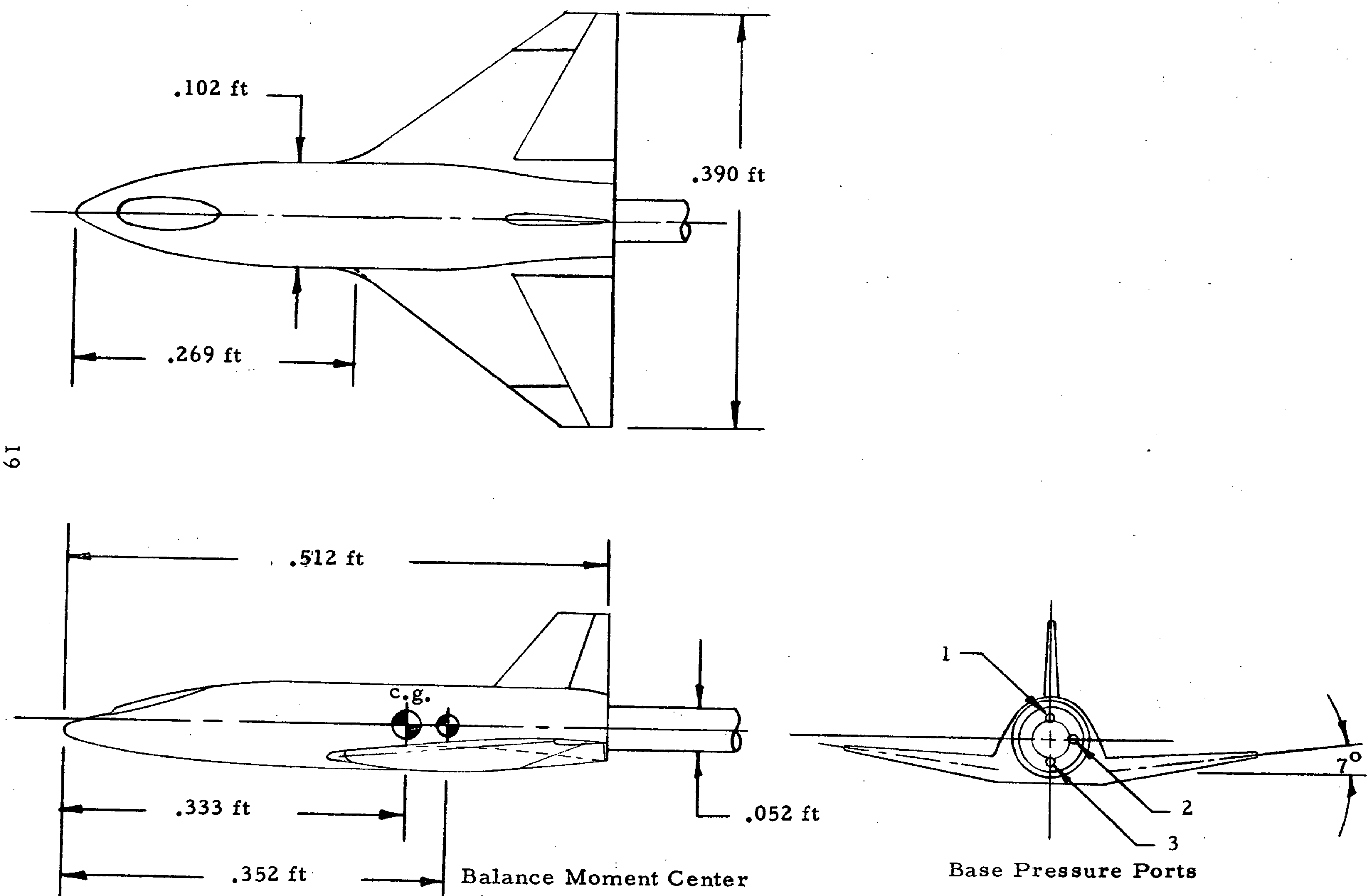

Fig.2a- General Arrangement – Orbiter Model 2A

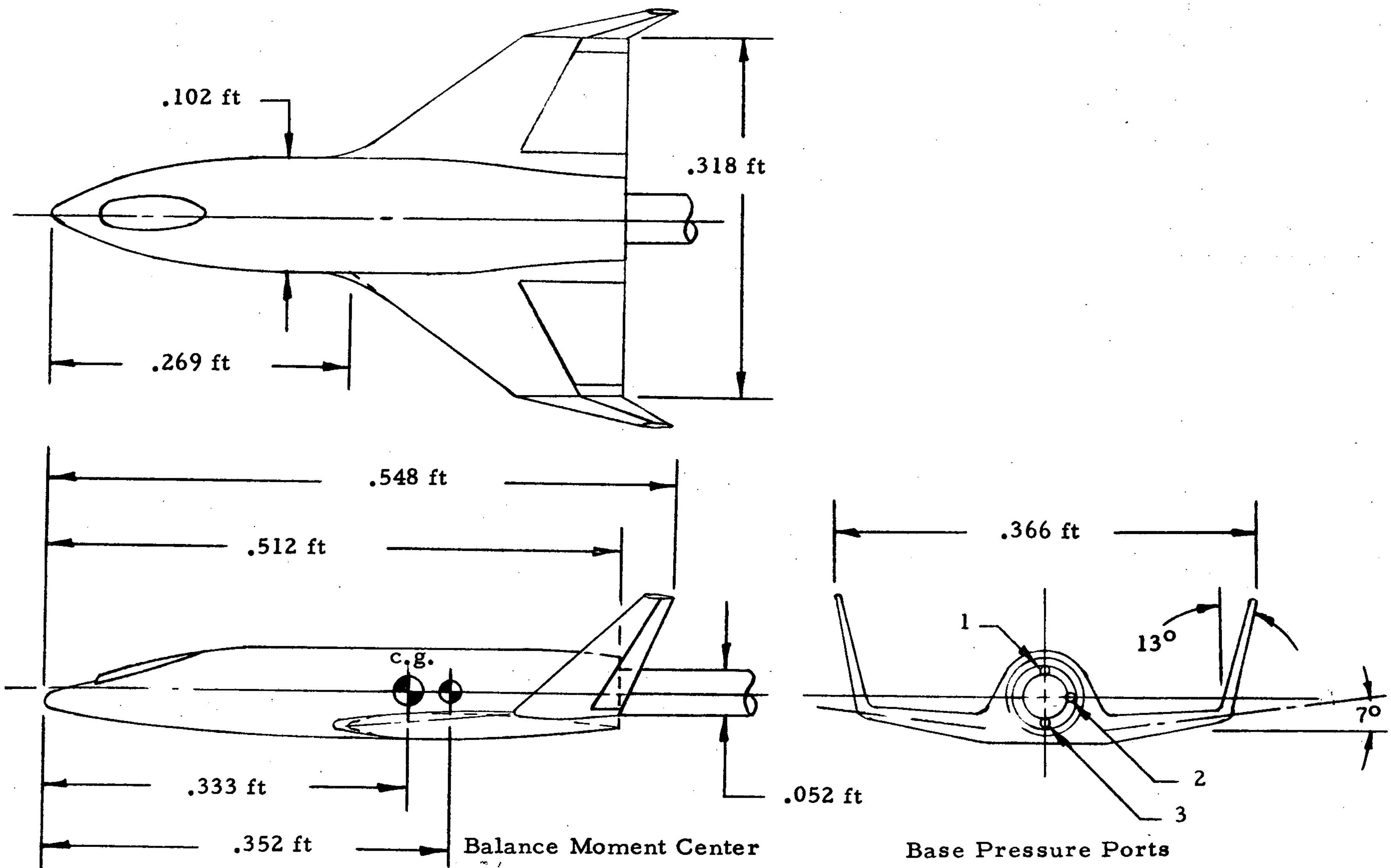

Fig.2b- General Arrangement — Orbiter Model 2B

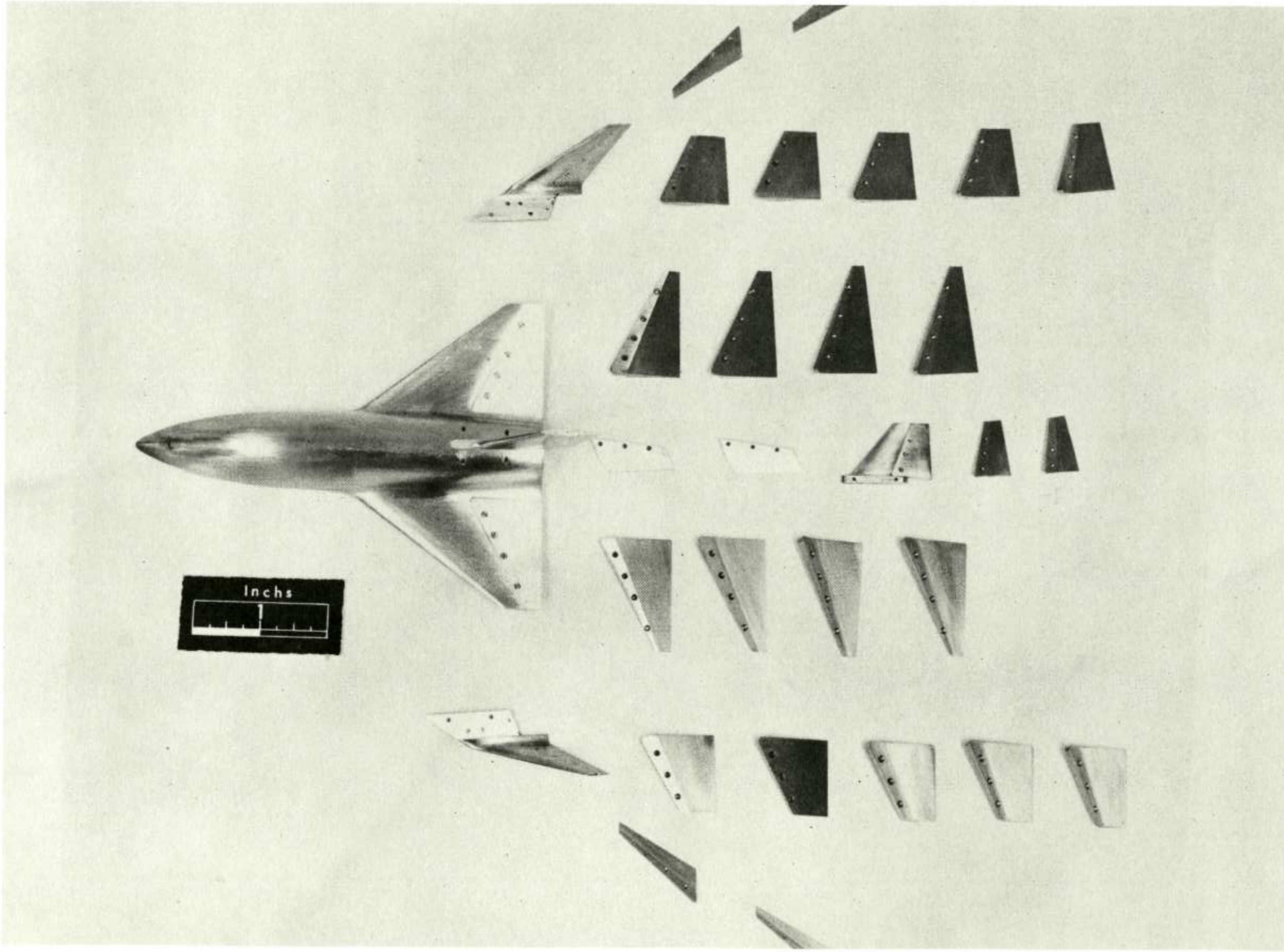

Fig. 3 - HCR Orbiter and Associated Model Parts

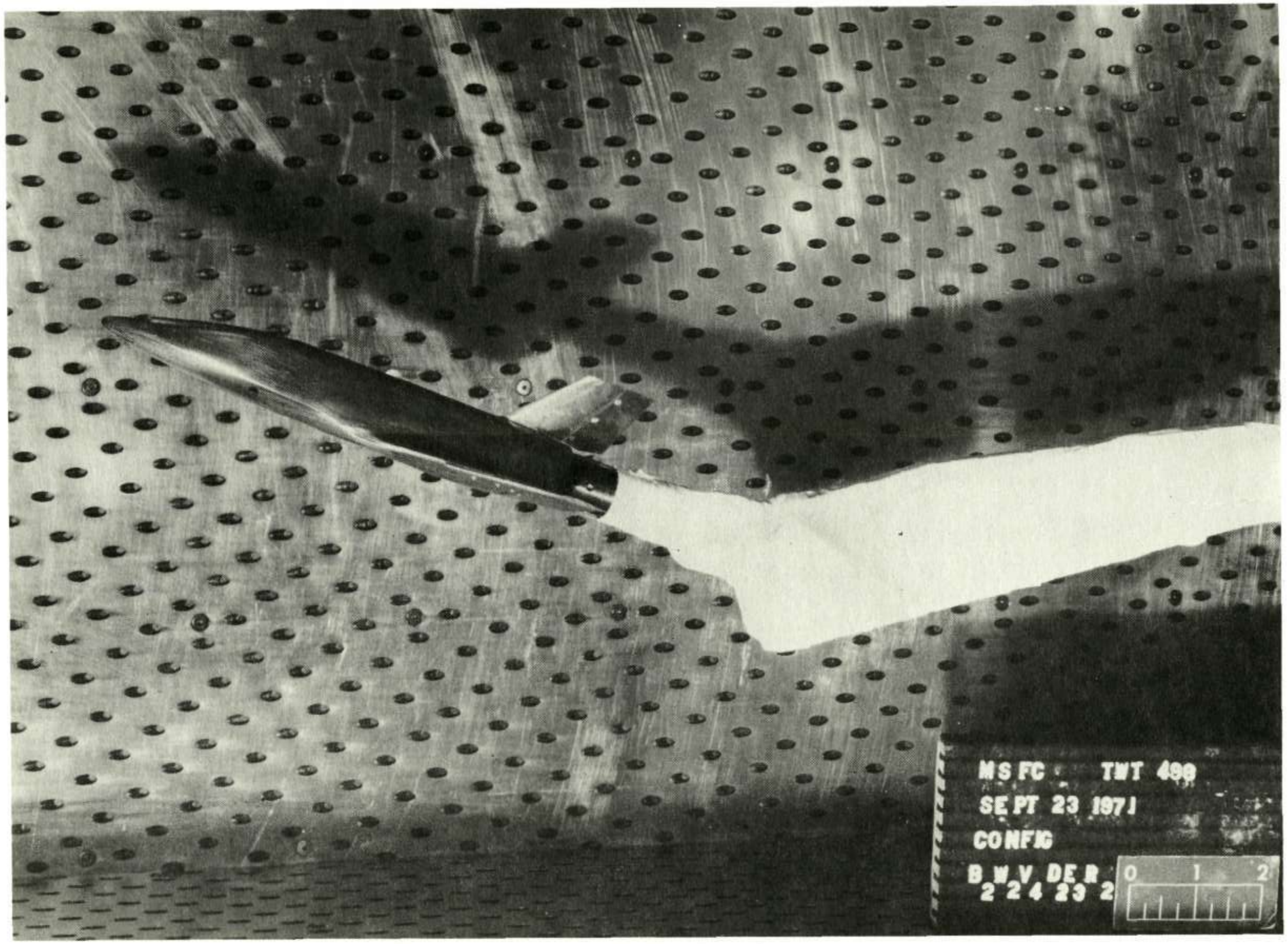

Fig. 4a - Installation Photograph, Model 2A (TWT 498)

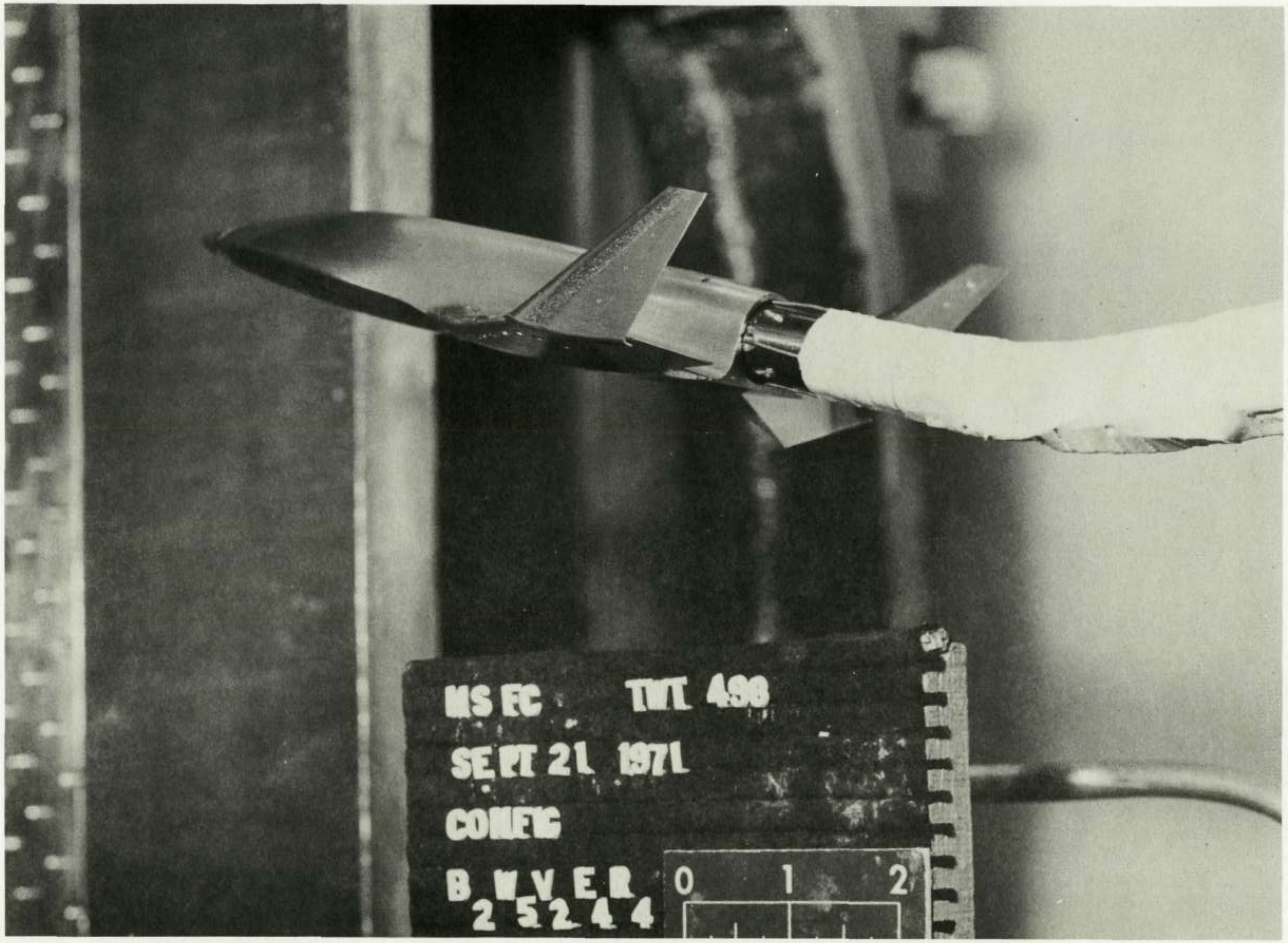

Fig. 4b - Installation Photograph, Model 2B (TWT 498)

2.2 STATIC STABILITY AND CONTROL STUDY OF A 0.004-SCALE MODEL ORBITER (TWT 542)

2.2.1 Test Purpose

The NASA decision to adapt a parallel burn launch concept with an orbiter external Hydrogen-Oxygen (HO) fuel tank resulted in a redesign of the orbiter airframe. The purpose of this test was to determine performance and stability and control for this new orbiter. The test was conducted at Mach numbers from .6 to 4.96, at angles of attack from -4 to 30 degrees and angles of side slip from -6 to 6 degrees at angles of attack of 0 and 10 degrees. A pretest report for this study was published in May 1972 (Ref. 9).

2.2.2 Test Facility

The test was conducted in the MSFC 14 x 14-Inch Trisonic Wind Tunnel. See Section 2.1.2 for a description of this facility.

2.2.3 Model Description

A sketch of the model is shown in Fig. 5 and installation photographs are included as Fig. 6. The model nomenclature is as follows:

Symbol	Description
A1	abort SRM pods
B1	orbiter body, including canopy and housing along top centerline
B2	B1 with off-block for body alone
P1	ACPS pods (wing upper surface)
V11	twin vertical tails (5-degree LE semi vertex angle)
W4	wing (including glove)
R2	nozzle shroud
F2	body flap

The model was designed and constructed by Lockheed-Huntsville. The body and wings are made of aluminum and the vertical tail and control surfaces were fabricated from 17-4 PH stainless steel. Figure 7 is a photograph of the completed model showing all component parts.

2.2.4 Data Reduction

Model forces and moments were measured by MSFC balance 201. All forces and moments were reduced to coefficient form using the reference dimensions shown in Table 4. The data were corrected for sting deflections and weight tares.

The data were entered in the Chrysler SADSAC program and published as a data report (Ref. 20).

2.2.5 Discussion

An outline of the configurations tested is shown in Table 5. This was the first test of the new NASA orbiter configuration. As such, the data were of extreme interest to MSFC and the Manned Spacecraft Center (MSC). Unfortunately this test was severely curtailed by failure of the roll gage of the balance, requiring that all runs after the failure be pitch plane runs only. Wind tunnel occupancy time for the shortened test was 58 hours.

Table 4

0.004-SCALE SPACE SHUTTLE ORBITER
REFERENCE DIMENSIONS

Parameter	Full Scale	Model Scale
Reference Area (S_{ref}) (Wing Theoretical Area)	3420.0 ft^2	7.880 in^2
Reference Length (ℓ_{ref}) (M.A.C.)	507.0 in.	2.028 in.
Reference Span (b_{ref}) (Wing Span)	1115.0 in.	4.460 in.
Balance Location (BMC) (Balance Moment Center) (from Nose)	—	3.883 in.
Moment Reference Center (MRP) (0.70 ℓ_B) (from nose)	920.5 in.	3.682 in.
Base Area (A_b)	317.7 ft^2	0.732 in^2
Cavity Area (A_c)	—	0.314 in^2

Table 5

RUN SCHEDULE FOR TWT 542

DATA SET IDENTIFIER	CONFIGURATION	SCHD. α	SCHD. β	PARAMETERS/VALUES δ_{eL}	δ_{eR}	δ_{rFL}	δ_{rFR}	NO. of RUNS	MACH NUMBERS (OR ALTERNATE INDEPENDENT VARIABLE) δ_F		0.6	0.9	1.2	1.46	1.96	3.48	4.96			
	B1F2W4V11P1	A	0	0°	0°	0°	0°		0°		✓	✓	✓		✓	✓	✓			
		B									✓	✓	✓							
		C													✓	✓	✓			
		0	D								✓	✓	✓							
		10	D								✓	✓	✓							
	B1F2W4V11P1	A	0	-10°	-10°	0°	0°		0°		✓	✓	✓		✓		✓			
		B									✓	✓	✓							
		C													✓		✓			
		0	D								✓	✓	✓							
		A	0	-30°	-30°						✓	✓	✓		✓		✓			
		B									✓	✓	✓							
		C													✓		✓			
		A		+10°	+10°						✓	✓	✓		✓		✓			
		B									✓	✓	✓							
		C													✓		✓			
	B1F2W4V11P1A1	A									✓	✓	✓							
		A		-10°	-10°						✓	✓	✓							
		A		0°	0°						✓	✓	✓							
		B		0°	0°						✓	✓	✓							

1 7 13 19 25 31 37 43 49 55 61 67 75 76

COEFFICIENTS: → IDPVAR(1) | IDPVAR(2) | NDV

α or β SCHEDULES
α: A = -4° to 10° by $\Delta\alpha$ = 2°; B = 10° to 20° by $\Delta\alpha$ = 2°; C = 10° to 30° by $\Delta\alpha$ = 2°
β: B = -6°, -3°, -2°, -1°, 0°, 1°, 2°, 3°, 6°

Table 5 (Continued)

DATA SET IDENTIFIER	CONFIGURATION	SCHD. α	SCHD. β	PARAMETERS/VALUES δ_{eL}	δ_{eR}	δ_{FEL}	δ_{FER}	NO. of RUNS	MACH NUMBERS (OR ALTERNATE INDEPENDENT VARIABLE) δ_F		0.6	0.9	1.2	1.46	1.96	3.48	4.96			
	B1F2W4V11P1A1	0	D	0°	0°	0°	0°		0°		✓	✓	✓							
	↓	0	D	-10°	-10°	0°	0°				✓	✓	✓							
	B1F2W4V11P1	A	0	0°	0°	30°/0°	30°/0°				✓	✓	✓							
		0	D								✓	✓	✓							
		10	D			↓	↓				✓	✓	✓							
		A	0			30°/-30°	30°/-30°				✓	✓	✓							
		0	D								✓	✓	✓							
		10									✓	✓	✓							
	↓	20	↓								✓	✓	✓							
	B1F2W4V11P1R2	A	0								✓	✓	✓							
		0	D								✓	✓	✓							
		10	D			↓	↓				✓	✓	✓							
		A	0			30°/0°	30°/0°				✓	✓	✓							
		0	D								✓	✓	✓							
		10	D			↓	↓				✓	✓	✓							
		A	0			0°	0°				✓	✓	✓		✓		✓			
		0	D								✓	✓	✓							
	↓	10	D			↓	↓				✓	✓	✓							
	B1F2W4V11P1A1	A	0			30°/0°	30°/0°				✓	✓	✓							
	↓	0	D	↓	↓	30°/0°	30°/0°		↓		✓	✓	✓							

1 7 13 19 25 31 37 43 49 55 61 67 75 76

COEFFICIENTS: → IDPVAR(1) | IDPVAR(2) | NDV

α or β SCHEDULES

α: A = -4° to 10° by Δα = 2°

β: D = -6°, -3°, -2°, -1°, 0°, 1°, 2°, 3°, 6°

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Table 5 (Concluded)

DATA SET IDENTIFIER	CONFIGURATION	SCHD. α	SCHD. β	PARAMETERS/VALUES δ_{eL}	δ_{eR}	δ_{rFL}	δ_{rFR}	NO. of RUNS	MACH NUMBERS (OR ALTERNATE INDEPENDENT VARIABLE) δ_F		0.6	0.9	1.2	1.46	1.96	3.48	4.96			
	B1F2W4V11P1A1	10	D	0°	0°	30°/0°	30°/0°		0		✓	✓	✓							
	B1F2W4V11P1	A	0	↓	↓	0°	0°		64°						✓	✓	✓			
	↓	C	↓	↓	↓	0°	0°		64°						✓	✓	✓			
	B1F2W4P1	A	↓	↓	↓	—	—		0		✓	✓	✓		✓		✓			
	B2	A	0	—	—	—	—		—		✓	✓	✓		✓	✓	✓			
	↓	B	↓	↓	↓	↓	↓		↓		✓	✓	✓							
	↓	C	↓	↓	↓	↓	↓		↓						✓	✓	✓			
	B1F2W4V11P1 (NO CRIT)	A	0	+10°	+10°	0°	0°		0°		✓		✓		✓					
	↓	↓	↓	0°	0°	↓	↓		↓		✓		✓		✓					
	↓	↓	↓	-10°	-10°	↓	↓		↓		✓		✓		✓					

1 7 13 19 25 31 37 43 49 55 61 67 75 76

COEFFICIENTS: → IDPVAR(1) | IDPVAR(2) | NDV

α or β SCHEDULES

α: A = -4° to 10° by Δα = 2°; B = 10° to 20° by Δα = 2°; C = 10° to 30° by Δα = 2°

β: A = -6°, -3°, -2°, -1°, 0°, 1°, 2°, 3°, 6°

Note: All dimensions are model scale, inches

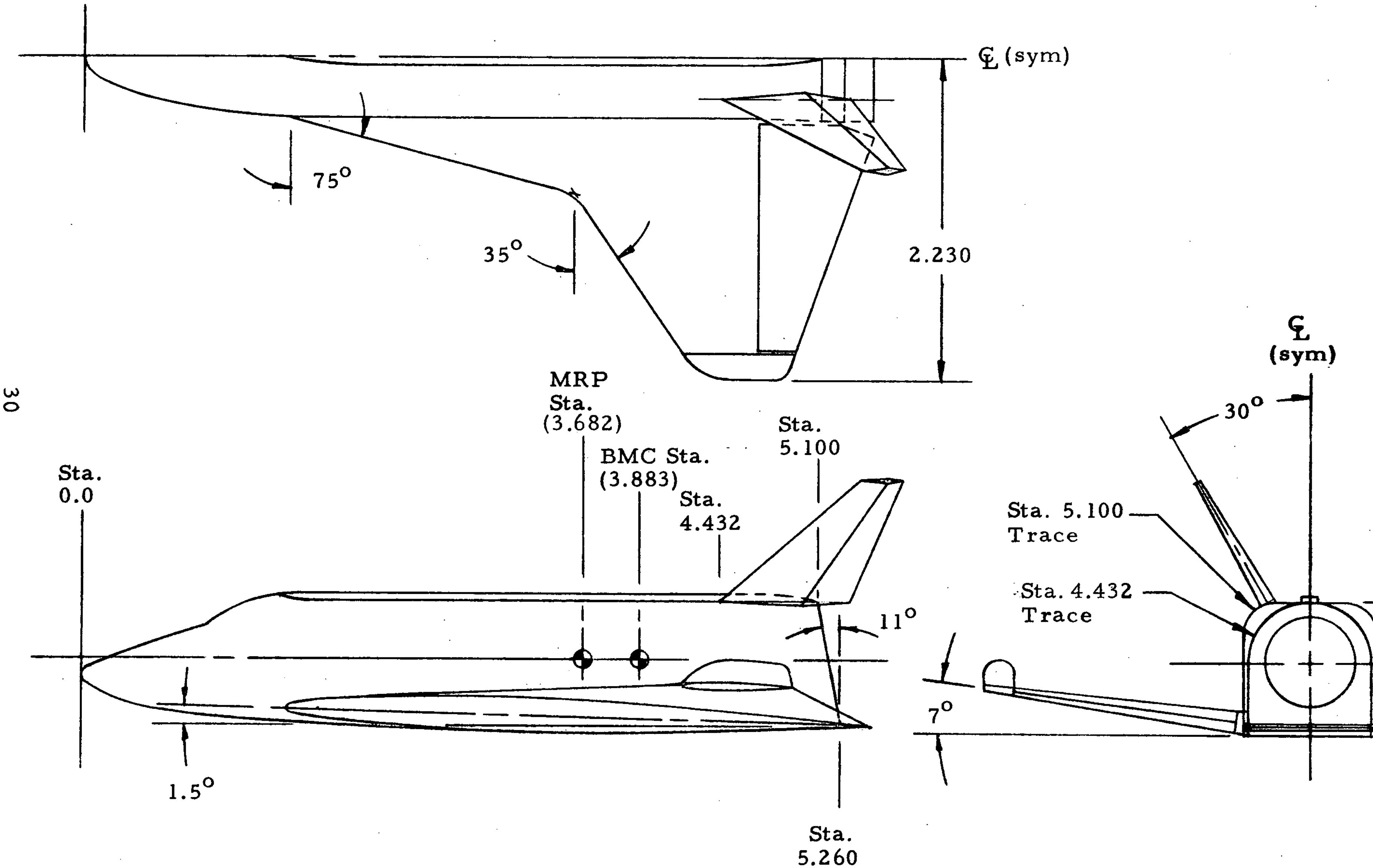

Fig. 5 - General Arrangement, Space Shuttle Double Delta Orbiter

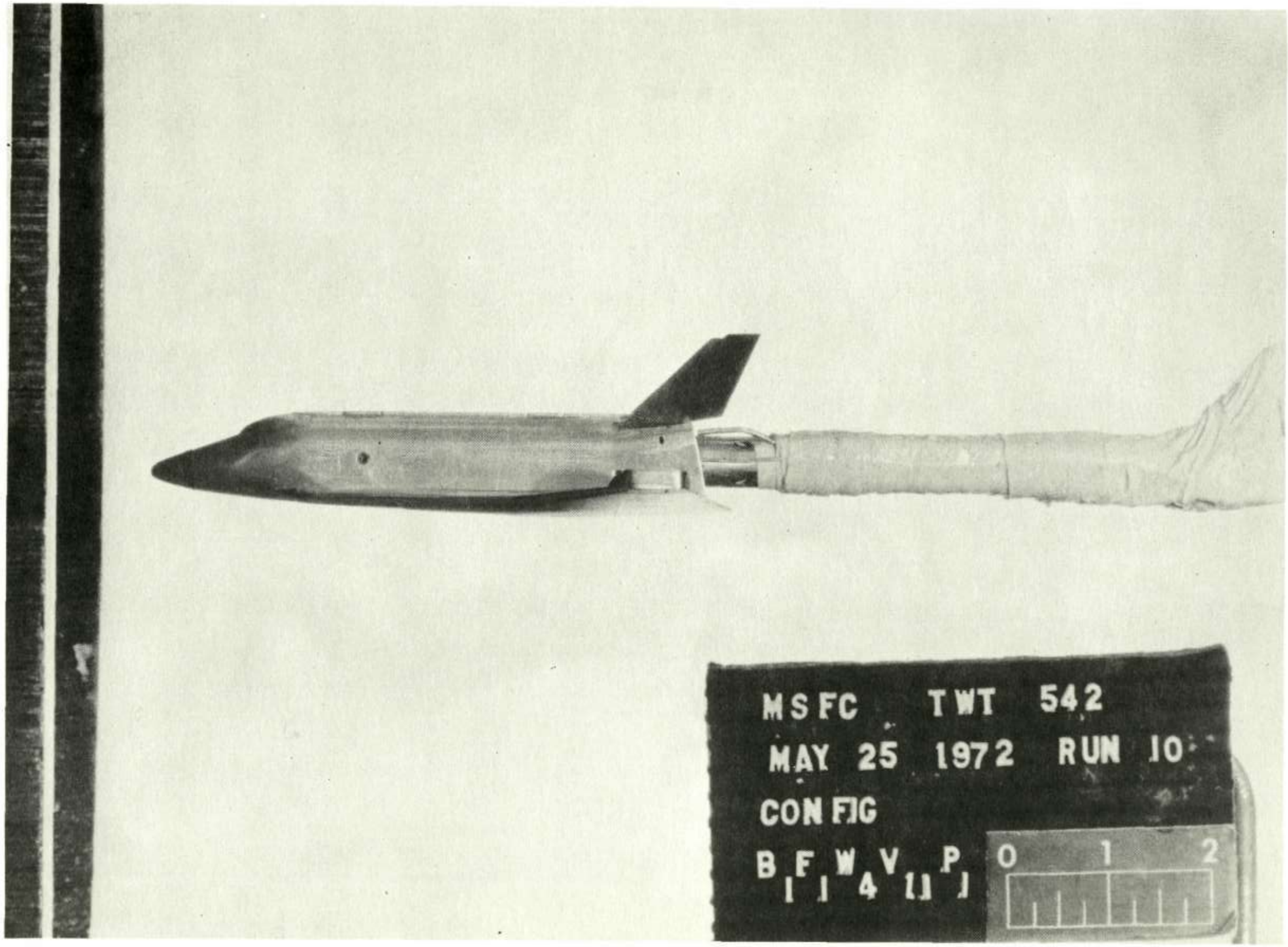

Fig. 6a - Installation Photograph, Double Delta Orbiter (TWT 542)

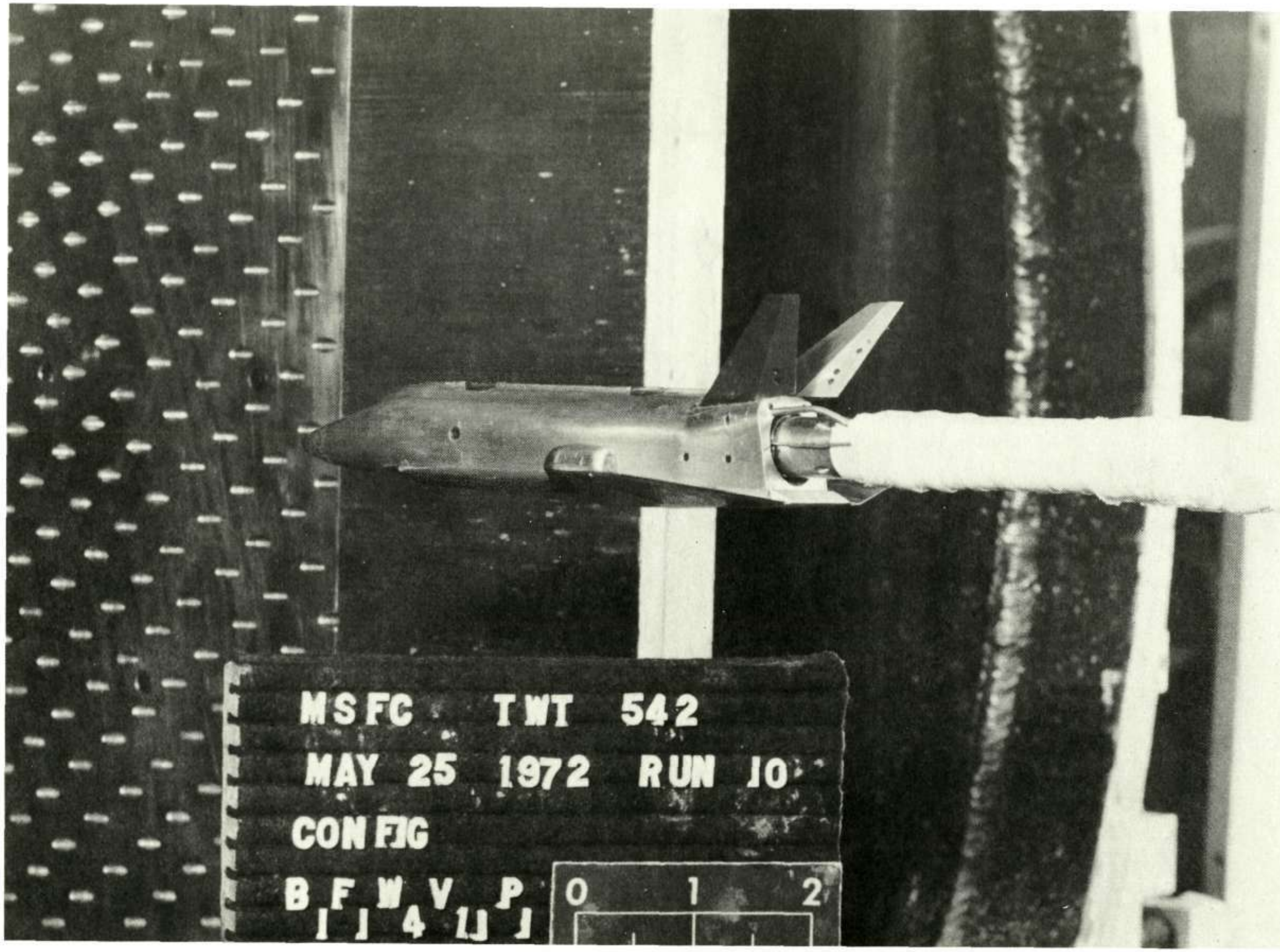

Fig. 6b - Installation Photograph, Double Delta Orbiter (TWT 542)

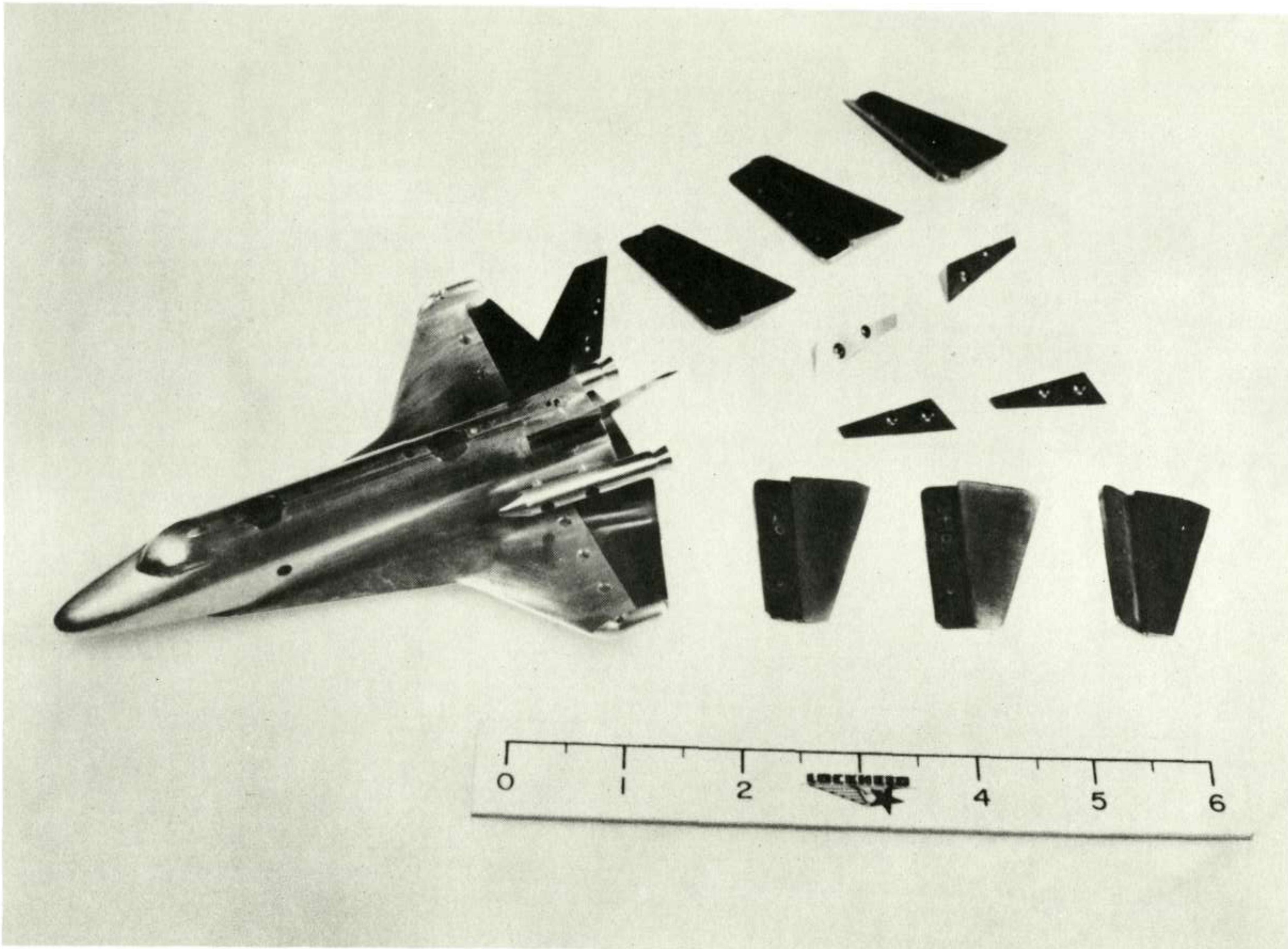

Fig. 7 - Double Delta Orbiter with Associated Parts

2.3 CRUISE ENGINE PLACEMENT AND LATERAL-DIRECTIONAL STABILITY STUDY FOR A 0.015-SCALE FLYBACK BOOSTER (NSRDC 3310)

2.3.1 Test Purpose

Earlier tests (Ref. 1) of the Lockheed-Huntsville modified McDonnell-Douglas flyback booster had shown unfavorable lateral-directional characteristics (NSRDC 3110) and suggested favorable cruise engine placement location (NSRDC 3210). Further modifications to improve these areas were investigated in tests conducted during August 1971. The model was tested at Mach numbers of 0.4 to 1.2 at angles of attack from -4 to 20 degrees and at angles of sideslip from -6 to 6 degrees while at angles of attack of 0, 6 and 15 degrees. A pretest report was published in August 1971 for this test (Ref. 4).

2.3.2 Test Facility

The wind tunnel used for this test was the 7 x 10-foot transonic facility at the Naval Ship Research & Development Center. This facility is described in detail in Ref. 21, from which the following excerpts were taken.

> "The drive system is composed of two 12,000 hp synchronous electric motors which operate at 720 revolutions per minute. Each motor is connected to a fan by a variable-speed dynamatic coupling. There are two stages of axial flow fans, each 18 feet in diameter.
>
> "Two air dryers maintain condensation-free flow in the tunnel circuit at all Mach numbers.
>
> "The tunnel cooling system consists of a heat exchanger through which water is circulated to maintain a stagnation temperature of less than 140°F in the tunnel circuit.
>
> "Evacuation pumps provide a range of test stagnation pressures from atmospheric to about 700 lb/ft^2. By venting the test section area to atmospheric pressure, a stagnation pressure of approximately 1.75 atm can be reached at a maximum Mach number of 0.9. The wind tunnel operates continuously over a range of Mach numbers from 0.4 to 1.17 at the reduced pressure condition.

"The test section is rectangular and measures 7 ft in height and 10 ft in width. The floor and ceiling are slotted and have diffuser flaps at the downstream end of each slot to control flow reentry and Mach number.

"The main support system, a cantilevered boom and sting mounted on a vertical strut, has three degrees of freedom, all of which are resolved about a fixed point in the test section (tunnel station 100.787). The range of angular displacements are:

Angle of Attack	-4 to 29 deg
Sideslip	-25 to 25 deg
Roll	-180 to 180 deg

"As many as 12 forces and/or moments may be read out without additional equipment. A Fischer-Porter pressure recording unit will measure and read out as many as 100 pressures.

"The raw data are stored on a punched paper tape, and are tabulated by a Flexowriter."

2.3.3 Model Description

The model tested was a 0.015-scale modified McDonnel-Douglas flyback booster. A general arrangement of this model is shown in Fig. 8. The basic model can be tested with high or low wing positions, high or low canard positions, variable wing and canard incidence, variable wing dihedral, variable body length, wing tip or dorsal vertical fins, and canard flap, elevon and rudder control deflections.

Model nomenclature for the various model components is listed below.

B1	modified MDAC 256-14 body (ℓ = 3.453 ft)
C2	aerodynamic canard (S_e = 0.169 ft^2)
D1	dorsal fin (S_e = 0.442 ft^2)
F1	canard trailing edge flap (c_f = 20%c)
F2	canard trailing edge flap (c_f = 40%c)
G5	dummy sidebody mounted engine pods, high position

G6	dummy sidebody mounted engine pods, low position
T1	dorsal fin end plate. Trailing edge flush with dorsal tip trailing edge ($S = 0.087\ ft^2$)
T2	dorsal fin end plate. Trailing edge flush with dorsal tip trailing edge ($S = 0.070\ ft^2$)
V1	wing tip vertical fin ($S_e = 0.248\ ft^2$ each)
V2	wing tip extension ($S_e = 0.15\ ft^2$ each)
V3	identical to V1 except rolled out $40^\circ 2'$
V4	identical to V1 except mounted inverted
V5	twin ventral fins constructed of sheet aluminum. Trailing edge of fin mounted flush with booster base. Rolled out 10 deg from vertical ($S = 0.113\ ft^2$ each)
W1	baseline wing ($S_e = 0.891\ ft^2$)

The model was designed and constructed at the Naval Ship Research and Development Center, Carderock, Maryland. Figure 9 shows several installed configurations.

2.3.4 Data Reduction

Model forces and moments were measured by NSRDC balance TSB-24. All forces and moments were reduced to nondimensional coefficients. Reference dimensions used for data are presented in Table 6. The data were corrected for tunnel flow angularities and sting deflections. Axial force was corrected for weight tares.

The data were entered in the Chrysler SADSAC program, and published as a data report (Ref. 22).

2.3.5 Discussion

Several combinations of vertical fins and wing dihedral angles were investigated during the test to gather information on the vehicle lateral-directional

characteristics. It is extremely difficult to achieve a proper ratio of lateral-to-directional stability for vehicles of this type because of the extreme aft (70% of body length) location of the center of gravity. Data from this test were used to select a configuration that would provide a reasonable ratio of lateral-to-directional stability while still maintaining a workable configuration with regard to performance and control, and having no geometrical restraints upon landing.

Previous tests had suggested that the best engine location would be forward on the body. This position exhibited less drag and was favorable from a weight and balance standpoint. However, there was a disadvantage as the original location of the engines (forward under the body) caused a loss in directional stability. The two engine locations investigated during this test did not exhibit the decreased directional stability of the former under the body location tests. Figure 10 shows the dummy engine pod.

Control deflections were also obtained during this test for the wing in the low position, and for the wing with negative dihedral in the high position.

Table 7 lists the configurations tested. The test required 56 hours of wind tunnel occupancy time to complete.

Table 6

0.015-SCALE BOOSTER REFERENCE DIMENSIONS (NSRDC 3310)

Parameter	Full Scale	Model Scale
Reference Area (S_{ref})	6020 ft^2	1.355 ft^2
Reference Length (ℓ_{ref}b)	229 ft	3.453 ft
Balance Location		
body station		2.694 ft
Moment Reference Center		
body station (c.g.)	172.92 ft	2.594 ft
water line (above ℄)	1.25 ft	.01875 ft
Base Area (A_b)		
high wing	1076 ft^2	0.242 ft^2

Table 7

RUN SCHEDULE FOR NSRDC 3310

DATA SET IDENTIFIER	CONFIGURATION	SCHD. α	SCHD. β	PARAMETERS/VALUES δ_e	δ_c	δ_a	δ_r	NO. of RUNS	PARAMETERS/VALUES CND POS	WNG POS	i_c	i_w	Γ_w	MACH NUMBERS 0.4	0.7	0.8	0.9	1.0		
	B1C2F1W1V2	A	0	0°	0°	0°	–		1	1	3°	0°	-7°40′	✓						
		0	A											✓						
		6												✓						
		15												✓						
	B1C2F1W1V2D1	A	0				0°							✓	✓	✓	✓	✓		
		0	A											✓	✓	✓	✓	✓		
		6												✓	✓	✓	✓	✓		
		15												✓	✓	✓	✓			
	B1C2F1W1V1D1	A	0											✓						
		0	A											✓						
		6												✓						
		15												✓						
	B1C2F1W1V1	A	0											✓						
		0	A											✓						
		6												✓						
		15												✓						
	B1C2F1W1V2	A	0				–						15°	✓						
		0	A											✓						
		6												✓						
		15												✓						

1 7 13 19 25 31 37 43 49 55 61 67 75 76

COEFFICIENTS: IDPVAR(1) IDPVAR(2) NDV

α or β SCHEDULES

α: A = -4°, 0°, 2°, 4°, 6°, 8°, 10°, 15°, 20

β: A = -6°, -3°, 0°, 3°, 6°

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Table 7 (Continued)

DATA SET IDENTIFIER	CONFIGURATION	SCHD. α	SCHD. β	PARAMETERS/VALUES δ_e	δ_c	δ_a	δ_r	NO. of RUNS	PARAMETERS/VALUES CND POS	WNG POS	i_c	i_w	Γ_w	MACH NUMBER 0.4	0.7	0.8	0.9	1.0		
	B1C2F1W1V1D1	A	0	0°	0°	0°	0°		1	1	3°	0°	7°40'	✓						
		0	A											✓						
		6												✓						
		15												✓						
	B1C2F1W1V1G6	A	0											✓	✓	✓	✓	✓		
		0	A											✓	✓	✓	✓	✓		
		6												✓	✓	✓	✓	✓		
		15												✓	✓	✓	✓	✓		
	B1C2F1W1V2D1	A	0							2			15°	✓						
		0	A											✓						
		6												✓						
		15												✓						
	B1C2F1W1V2	A	0				—							✓						
		0	A											✓						
		6												✓						
		15												✓						
	B1C2F1W1V1D1	A	0				0°						7°40'	✓						
		0	A											✓						
		6												✓						
		15												✓						

1 7 13 19 25 31 37 43 49 55 61 67 75 76

COEFFICIENTS: IDPVAR(1) | IDPVAR(2) | NDV

α or β SCHEDULES

α: A = -4°, 0°, 2°, 4°, 6°, 8°, 10°, 15°, 18°

β: A = -6°, -3°, 0°, 3°, 6°

Table 7 (Continued)

DATA SET IDENTIFIER	CONFIGURATION	SCHD. α	SCHD. β	PARAMETERS/VALUES δ_c	δ_c	δ_a	δ_r	NO. of RUNS	PARAMETERS/VALUES CND POS	WNG POS	i_c	i_w	Γ_w	MACH NUMBERS 0.4						
	B1C2F1W1V2D1T1	A	0	0°	0°	0°	0°		1	2	3°	0°	7°40'	✓						
		0	A											✓						
		6												✓						
		15												✓						
	B1C2F1W1V2D1T2	A	0											✓						
		0	A											✓						
		6												✓						
		15												✓						
	B1C2F1W1V2	A	0				—							✓						
		0	A											✓						
		6												✓						
		15												✓						
	B1C2F1W1V1	A	0	-20°			0°							✓						
		0	A											✓						
		6												✓						
		15												✓						
		A	0	-10°										✓						
		0	A											✓						
		6												✓						
		15												✓						

1 7 13 19 25 31 37 43 49 55 61 67 75 76

COEFFICIENTS: IDPVAR(1) IDPVAR(2) NDV

α or β SCHEDULES

α: A = -4°, 0°, 2°, 4°, 6°, 8°, 10°, 15°, 18°

β: A = -6°, -3°, 0°, 3°, 6°

Table 7 (Continued)

DATA SET IDENTIFIER	CONFIGURATION	SCHD.		PARAMETERS/VALUES				NO. of RUNS	PARAMETERS/VALUES					MACH NUMBERS						
		α	β	δ_e	δ_c	δ_a	δ_r		CND POS	WNG POS	i_c	i_w	Γ_w	0.4						
	B1C2F1W1V1	A	0	10°	0°	0°	0°		1	2	3°	0°	7°40'	✓						
		0	A											✓						
		6												✓						
		15												✓						
	B1C2F2W1V1	A	0		20°									✓						
		0	A											✓						
		6												✓						
		15												✓						
	B1C2F1W1V1	A	0	20°	0°									✓						
		0	A											✓						
		6												✓						
		15												✓						
		A	0	30°										✓						
		0	A											✓						
		6												✓						
		15												✓						
		A	0	0°		10°								✓						
		0	A											✓						
		6												✓						
		15												✓						

1 7 13 19 25 31 37 43 49 55 61 67 75 76

COEFFICIENTS: → IDPVAR(1) | IDPVAR(2) | NDV

α or β SCHEDULES

α: A = -4°, 0°, 2°, 4°, 6°, 8°, 10°, 15°, 18°

β: A = -6°, -3°, 0°, 3°, 6°

Table 7 (Continued)

PARAMETERS/VALUES | MACH NUMBERS

DATA SET IDENTIFIER	CONFIGURATION	SCHD. α	SCHD. β	PARAMETERS/VALUES δ_e	δ_c	δ_a	δ_r	NO. of RUNS	END POS	WNG POS	i_c	i_w	Γ_w	0.4
	B1C2F1W1V1	A	0	0°	0°	20°	0°		1	2	3°	0°	7°40'	✓
		0	A											✓
		6												✓
		15												✓
		A	0			0°	-5°							✓
		0	B											✓
		6												✓
		15												✓
		0					-10°							✓
		6												✓
		15												✓
	B1C2F1W1V2D1	A	0	-20°			0°			1			-7°40'	✓
		0	A											✓
		6												✓
		15												✓
		A	0	-10°										✓
		0	A											✓
		6												✓
		15												✓

1 7 13 19 25 31 37 43 49 55 61 67 75 76

COEFFICIENTS: IDPVAR(1) | IDPVAR(2) | NDV

α or β SCHEDULES

α: A = -4°, 0°, 2°, 4°, 6°, 8°, 10°, 15°, 18°

β: A = -6°, -3°, 0°, 3°, 6°

β: A = -6°, 0°, 6°

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Table 7 (Continued)

DATA SET IDENTIFIER	CONFIGURATION	SCHD. α	SCHD. β	PARAMETERS/VALUES δ_e	δ_c	δ_a	δ_r	NO. of RUNS	PARAMETERS/VALUES CND POS	WNG POS	i_c	i_w	Γ_w	MACH NUMBERS 0.4						
	B1C2F1W1V2D1	A	0	10°	0°	0°	0°		1	1	3°	0°	-7°40'	✓						
		0	A											✓						
		6												✓						
		15												✓						
	B1C2F2W1V2D1	A	0		20°									✓						
		0	A											✓						
		6												✓						
		15												✓						
	B1C2F1W1V2D1	A	0	20°	0°									✓						
		0	A											✓						
		6												✓						
		15												✓						
		A	0	30°										✓						
		0	A											✓						
		6												✓						
		15												✓						
		A	0	0°			10°							✓						
		0	A											✓						
		6												✓						
		15												✓						

1 7 13 19 25 31 37 43 49 55 61 67 75 76

COEFFICIENTS: IDPVAR(1) | IDPVAR(2) | NDV

α or β SCHEDULES

α: A = -4°, 0°, 2°, 4°, 6°, 8°, 10°, 15°, 18°

β: A = -6°, -3°, 0°, 3°, 6°

Table 7 (Continued)

DATA SET IDENTIFIER	CONFIGURATION	SCHD. α	SCHD. β	PARAMETERS/VALUES δ_e	δ_c	δ_a	δ_r	NO. of RUNS	PARAMETERS/VALUES CND POS	WNG POS	i_e	i_w	Γ_w	MACH NUMBERS 0.4						
	B1C2F1W1V2D1	A	0	0°	0°	20°	0°		1	1	3°	0°	-7°40'	✓						
		0	A											✓						
		6												✓						
		15												✓						
		0	B			0°	5°							✓						
		6												✓						
		15												✓						
		0					10°							✓						
		6												✓						
		15												✓						
	B1C2F1W1V2V5D1	A	0				0°							✓						
		0	A											✓						
		6												✓						
		15												✓						
	B1C2F1W1V3	A	0											✓						
		0	A											✓						
		6												✓						
		15												✓						

1 7 13 19 25 31 37 43 49 55 61 67 75 76

COEFFICIENTS: IDPVAR(1) IDPVAR(2) NDV

α or β SCHEDULES

α: A = -4°, 0°, 2°, 4°, 6°, 8°, 10°, 15°, 18°

β: A = -6°, -3°, 0°, 3°, 6°

Table 7 (Concluded)

DATA SET IDENTIFIER	CONFIGURATION	SCHD.		PARAMETERS/VALUES				NO. of RUNS	PARAMETERS/VALUES					MACH NUMBERS						
		α	β	δ_e	δ_c	δ_a	δ_r		CND POS	WNG POS	i_c	i_w	Γ_w	0.4	0.7	0.8	0.9			
	B1C2FW1V4	A	0	0°	0°	0°	0°		1	1	3°	0°	-7°40'	✓						
	↓	0	A	↓	↓	↓	↓		↓	↓	↓	↓	↓	✓						
	↓	6	↓	↓	↓	↓	↓		↓	↓	↓	↓	↓	✓						
	↓	15	↓	↓	↓	↓	↓		↓	↓	↓	↓	↓	✓						
	B1C2F1W1	A	0	↓	↓	↓	—		↓	↓	↓	↓	7°40'	✓						
	↓	0	A	↓	↓	↓	↓		↓	↓	↓	↓	↓	✓						
	↓	6	↓	↓	↓	↓	↓		↓	↓	↓	↓	↓	✓						
	↓	15	↓	↓	↓	↓	↓		↓	↓	↓	↓	↓	✓						
	B1C2F1W1V1G5	A	0	↓	↓	↓	0°		↓	↓	↓	↓	↓	✓	✓	✓	✓			
	↓	0	A	↓	↓	↓	↓		↓	↓	↓	↓	↓	✓	✓	✓	✓			
	↓	6	↓	↓	↓	↓	↓		↓	↓	↓	↓	↓	✓	✓	✓	✓			
	↓	15	↓	↓	↓	↓	↓		↓	↓	↓	↓	↓	✓	✓	✓	✓			
	B1C2F1W1V4	A	0	↓	↓	↓	↓		↓	↓	↓	↓	↓	✓						
	↓	0	A	↓	↓	↓	↓		↓	↓	↓	↓	↓	✓						
	↓	6	↓	↓	↓	↓	↓		↓	↓	↓	↓	↓	✓						
	↓	15	↓	↓	↓	↓	↓		↓	↓	↓	↓	↓	✓						

1 7 13 19 25 31 37 43 49 55 61 67 75 76

COEFFICIENTS: → IDPVAR(1) | IDPVAR(2) | NDV

α or β SCHEDULES

α: A = -4°, 0°, 2°, 4°, 6°, 8°, 10°, 15°, 18°

β: A = -6°, -3°, 0°, 3°, 6°

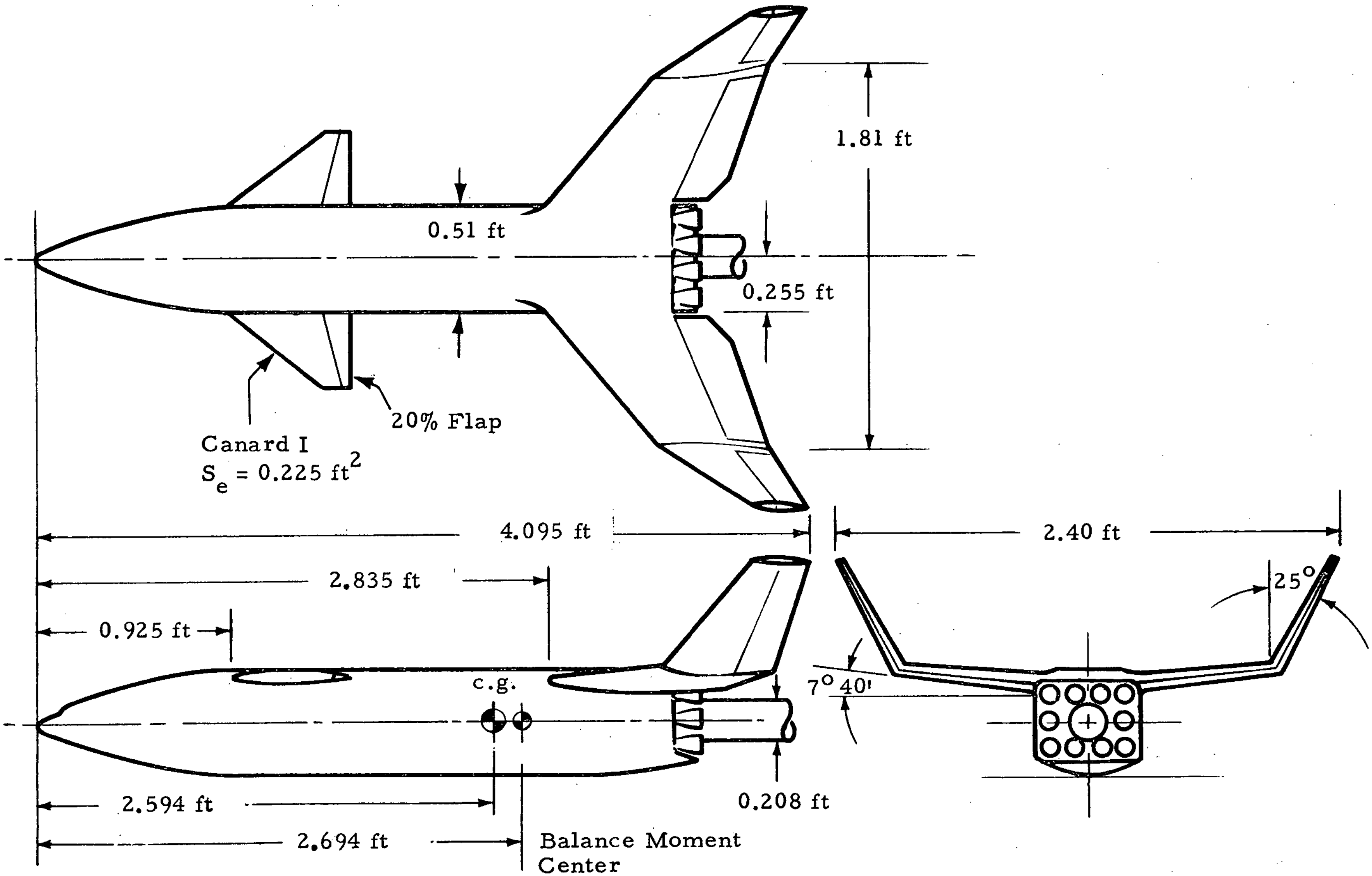


Fig. 8 - General Arrangement of the Baseline Flyback Booster Model

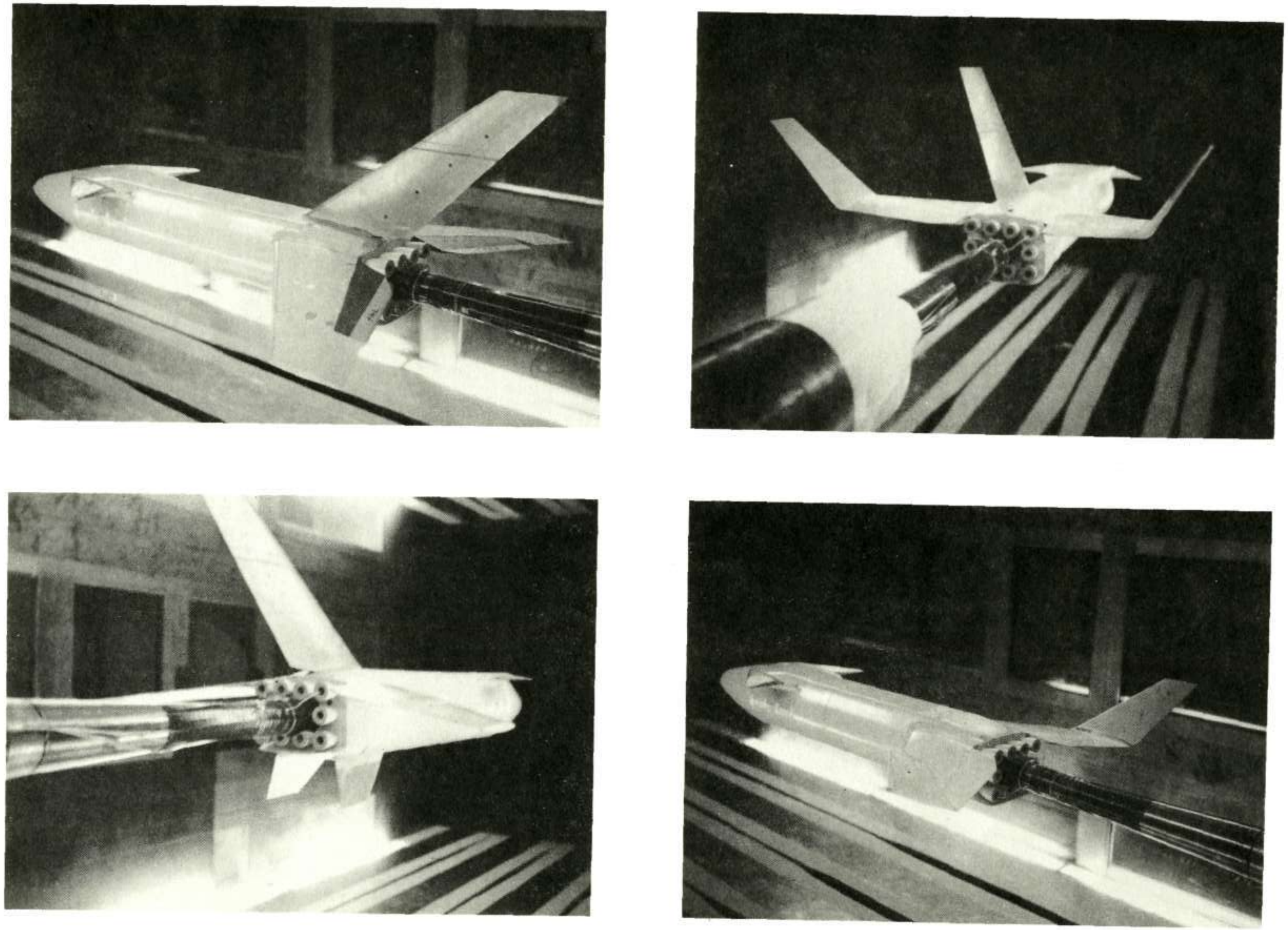


Fig. 9 - Installation Photographs, Flyback Booster (NSRDC 3310)

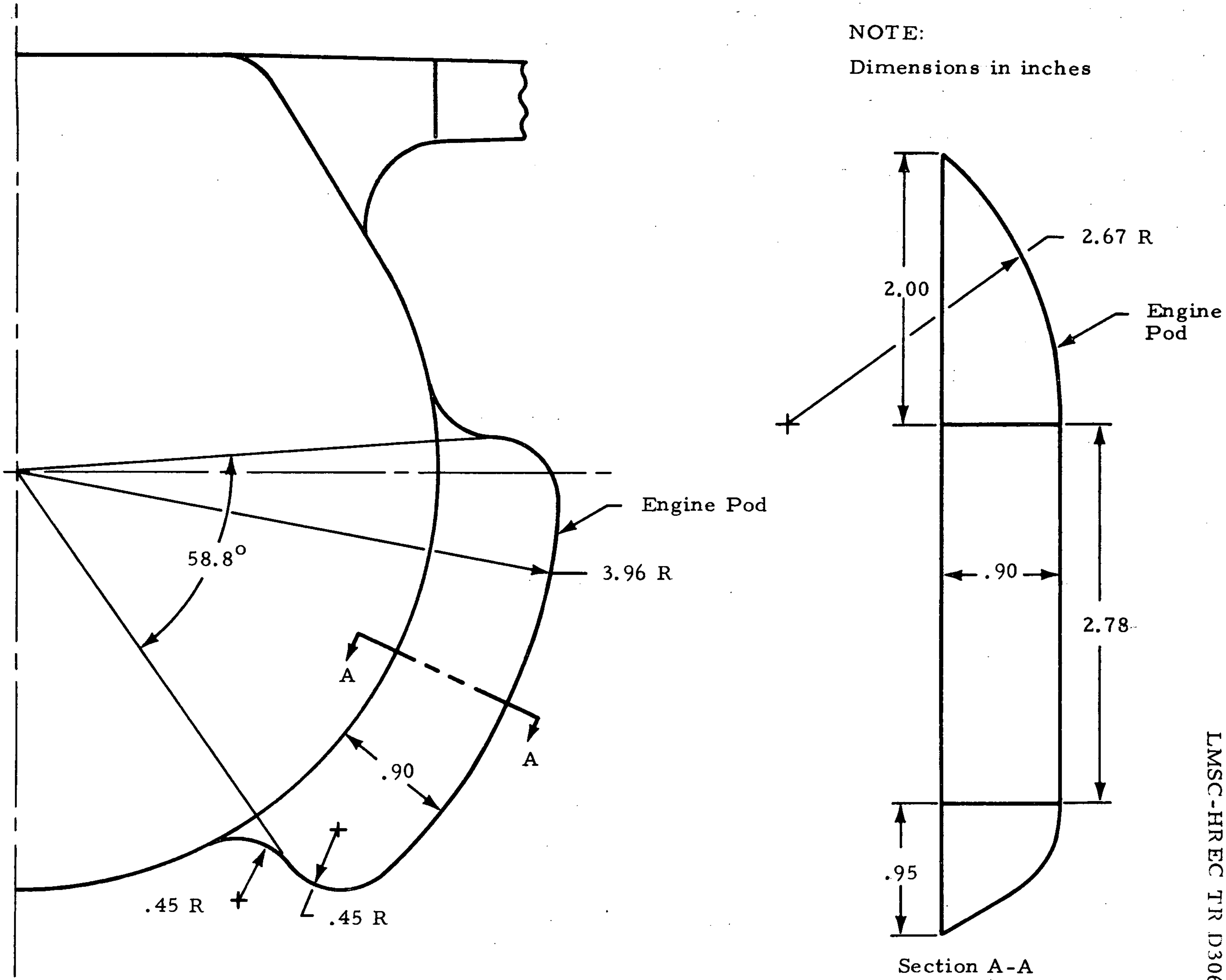


Fig. 10 - Flyback Booster Engine Configuration and Location of Dummy Engine Pods, G6

2.4 BASE DRAG REDUCTION STUDY ON A 0.015-SCALE FLYBACK BOOSTER (CAL-T-18-063)

2.4.1 Test Purpose

The base drag of the flyback booster is as much as 50% of the total vehicle drag at zero lift angle of attack. Any reduction of base drag would significantly improve cruise characteristics of the booster. Three methods of reducing base drag were evaluated during this test. Test conditions included a Mach number range of 0.4 to 1.1, an angle of attack range of -4 to 20 degrees and angles of sideslip from -6 to +6 degrees while at angles of attack of 0, 6 and 15 degrees. A pretest report for this study was published in September 1971 (Ref. 5).

2.4.2 Test Facility

The test was conducted in the 8 x 8-Foot Transonic Wind Tunnel of the Cornell Aeronautical Laboratory, Inc., Buffalo, N.Y. The tunnel is described in Ref. 23, from which the following excerpts were taken.

> "The tunnel has a perforated throat and an auxiliary pumping system for plenum pumping. The continuous circuit tunnel is capable of operating from 1/6 to 2-1/2 atm total pressure thereby providing a wide range of test Reynolds numbers as well as Mach numbers. The range of operating pressures is necessarily limited by the total power available at the higher Mach numbers.
>
> "Angles of roll and attack as established by the roll and vertical strut pitch mechanisms are accurate to within ±0.10 degree.... A considerable improvement in model accuracy can be realized by installing electrolytic bubbles inside the model thereby eliminating sting-balance deflections and sting joint hysteresis. Accuracies of ±0.02 degrees are possible with this system.
>
> "The storage capabilities for either auxiliary air or nitrogen consists of three farms.... The total storage capacity is approximately 280,000 cubic feet of gas at 3000 psig. The air is supplied from a 1000 hp Clark reciprocating air compressor which is rated at 2.365 pounds per second at 3000 psig and $-70^{\circ}F$ dew point for continuous duty.

"Thirty-three readouts are available for simultaneous reading of data.

"Digital data from the readouts are recorded in punch cards which are introduced into the system through an IBM 1442 card punch and reader."

2.4.3 Model Description

The basic model has been described previously in Section 2.3.3. For this test modified base regions were fitted to the basic model. Drawings of the modified regions are shown in Figs. 11 through 13. Figure 14 shows the actual base regions as installed on the model. The model nomenclature for this study is listed below.

Symbol	Description
B4	base plenum configuration
B5	base flap configuration
B6	base venting configuration
B7	same as B4 except has rocket nozzles removed
C2	aerodynamic canard (S_e = 0.169 ft^2)
F2	canard trailing edge flap (c_f = 40%c)
V1	wing tip vertical fin (S_e = 0.248 ft^2 each)
W3	baseline wing modified for new base shape

2.4.4 Data Reduction

Cornell balance number CAL-TASK-Mk-XIX was used to measure balance forces. Data were corrected for tunnel flow angularities. A bubble pack mounted in the model was used to measure angle of attack so no sting deflection corrections were necessary. Axial force was corrected for weight tares. All model forces and moments were reduced to coefficient form using the dimensions shown in Table 8.

The base flow plenum total pressure taps and instrumentation to compute mass flow rate from the base nozzles were fitted to monitor base flow conditions during that portion of the test.

The data were entered in the Chrysler SADSAC program, and published as a data report (Ref. 24). The tabulated data were also published as a Cornell data report (Ref. 25).

2.4.5 Discussion

The methods used in an attempt to reduce base drag were:

1. Base flaps were used to induce freestream air into the base region,
2. A vented base was employed to open the base region to freestream air, and
3. Air was blown into the base region.

All three of these methods depend upon the use of air with relatively high total energy to relieve the low pressure, stagnated air present in the base region. The fitting of these devices required that the base be reworked, so a short transonic study and a control effectiveness study was done to determine the aerodynamic effects of the modified base. A summary of the configurations tested is shown in Table 9.

None of the devices tested were particularly successful in reducing base axial force. There was very little or no change for the base flap or base vent methods and a significant increase for the blown base method. It is felt that the blowing base was unsuccessful because the nozzles were too localized and the flow velocity too high.

Twenty-eight wind tunnel occupancy hours were required to complete the test.

Table 8

0.015-SCALE BOOSTER REFERENCE DIMENSIONS (CAL-T-18-063)

Parameter	Full Scale	Model Scale
Reference Area (S_{ref})	6020 ft^2	1.355 ft^2
Reference Length ($\ell_{ref}b$)	229 ft	3.453 ft
Balance Location body station		2.694 ft
Moment Reference Center body station (c.g.) water line (above ℄)	 172.92 ft 1.25 ft	 2.594 ft .01875 ft
Base Area (A_b) high wing	 1076 ft^2	 0.242 ft^2

Table 9

RUN SCHEDULE FOR CAL-T-18-063

DATA SET IDENTIFIER	CONFIGURATION	SCHD. α	SCHD. β	PARAMETERS/VALUES δ_e	δ_c	$\dot{m}_b$		NO. of RUNS	MACH NUMBERS (OR ALTERNATE INDEPENDENT VARIABLE) 0.4	0.7	0.8	0.9	1.0	1.1						
	B4C2F2W3V1	A	0	0°	0°	0			✓	✓	✓	✓	✓	✓						
		0	A						✓	✓	✓	✓	✓	✓						
		6							✓	✓	✓	✓	✓	✓						
		15							✓	✓	✓	✓	✓	✓						
	B5C2F2W3V1	A	0						✓											
		0	A						✓											
		6							✓											
		15							✓											
	B6C2F2W3V1	A	0						✓											
		0	A						✓											
		6							✓											
		15							✓											
	B4C2F2W3V1	A	0	10°					✓											
		0	A						✓											
		6							✓											
		15							✓											
		A	0	-10°					✓											
		0	A						✓											
		6							✓											
		15							✓											

1 7 13 19 25 31 37 43 49 55 61 67 75 76

COEFFICIENTS: → IDPVAR(1) | IDPVAR(2) | NDV

α or β SCHEDULES

α: A = -4°, 0°, 2°, 4°, 6°, 8°, 10°, 15°, 20°

β: A = -6°, -3°, 0°, 3°, 6°

Table 9 (Continued)

DATA SET IDENTIFIER	CONFIGURATION	SCHD. α	SCHD. β	PARAMETERS/VALUES δ_e	δ_c	$\dot{m}_b$		NO. of RUNS	MACH NUMBERS (OR ALTERNATE INDEPENDENT VARIABLE) 0.4											
	B4C2F2W3V1	A	0	20°	0°	0			✓											
		0	A						✓											
		6							✓											
		15							✓											
		A	0	30°					✓											
		0	A						✓											
		6							✓											
		15							✓											
		A	0	0°	10°				✓											
		0	A						✓											
		6							✓											
		15							✓											
		A	0		20°				✓											
		0	A						✓											
		6							✓											
		15							✓											
		A	0	10°					✓											
		0	A						✓											
		6							✓											
		15							✓											

1 7 13 19 25 31 37 43 49 55 61 67 75 76

COEFFICIENTS: IDPVAR(1) IDPVAR(2) NDV

α or β SCHEDULES

α: A = -4°, 0°, 2°, 4°, 6°, 8°, 10°, 15°, 20°

β: A = -6°, -3°, 0°, 3°, 6°

Table 9 (Continued)

DATA SET IDENTIFIER	CONFIGURATION	SCHD. α	SCHD. β	PARAMETERS/VALUES δ_e	δ_c	$\dot{m}_b$		NO. of RUNS	MACH NUMBERS (OR ALTERNATE INDEPENDENT VARIABLE) 0.4
	B4C2F2W3V1	A	0	-10°	20°	0			✓
		0	A						✓
		6							✓
		15							✓
		A	0	+10°	10°				✓
		0	A						✓
		6							✓
		15							✓
		A	0	-10°					✓
		0	A						✓
		6							✓
		15							✓
		A	0	-20°	0°				✓
		0	A						✓
		6							✓
		15							✓
		A	0	0°		.353			✓
		0	A						✓
		6							✓
		15							✓

1 7 13 19 25 31 37 43 49 55 61 67 75 76

COEFFICIENTS: → IDPVAR(1) | IDPVAR(2) | NDV

α or β SCHEDULES

α: A = -4°, 0°, 2°, 4°, 6°, 8°, 10°, 15°, 20°

β: A = -6°, -3°, 0°, 3°, 6°

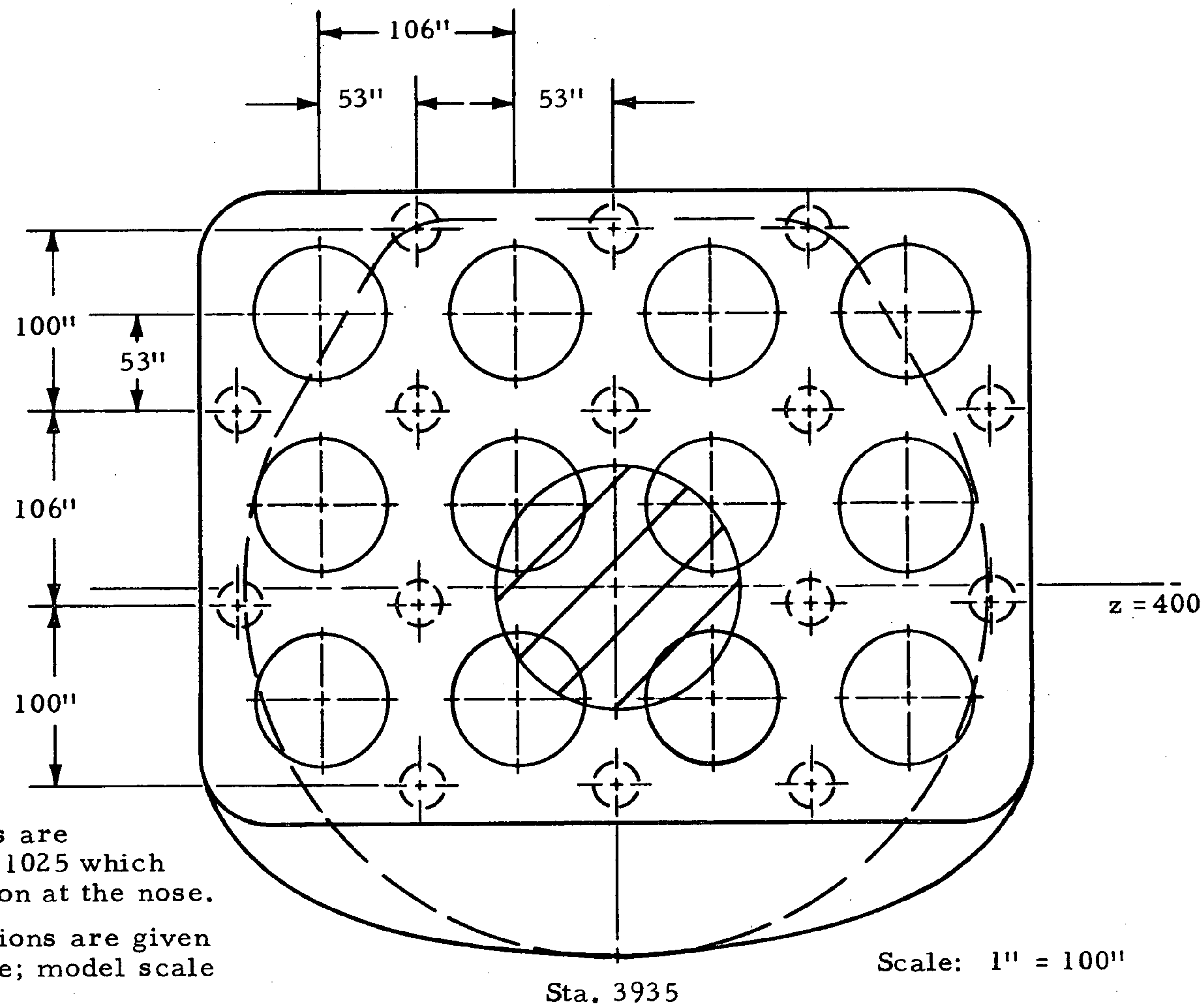
Table 9 (Concluded)

DATA SET IDENTIFIER	CONFIGURATION	SCHD. α	SCHD. β	PARAMETERS/VALUES δ_e	δ_c	$\dot{m}_b$		NO. of RUNS	MACH NUMBERS (OR ALTERNATE INDEPENDENT VARIABLE) 0.0	0.4										
	B4C2F2W3V1	0	0	0°	0°	VAR.				✓										
									✓											
										✓										
										✓										
	B7C2F2W3V1									✓										
	B5C2F2W3V1									✓										

1 7 13 19 25 31 37 43 49 55 61 67 75 76

COEFFICIENTS: IDPVAR(1) IDPVAR(2) NDV

α or β SCHEDULES



Note: (1) All stations are relative to 1025 which is the station at the nose.

(2) All dimensions are given in full scale; model scale is 0.015.

(3) Diameter of orifices is not fixed as yet and will be determined when mass flow rates are established.

Fig. 11a - Flyback Booster Base Plenum Orifice Location (End View)

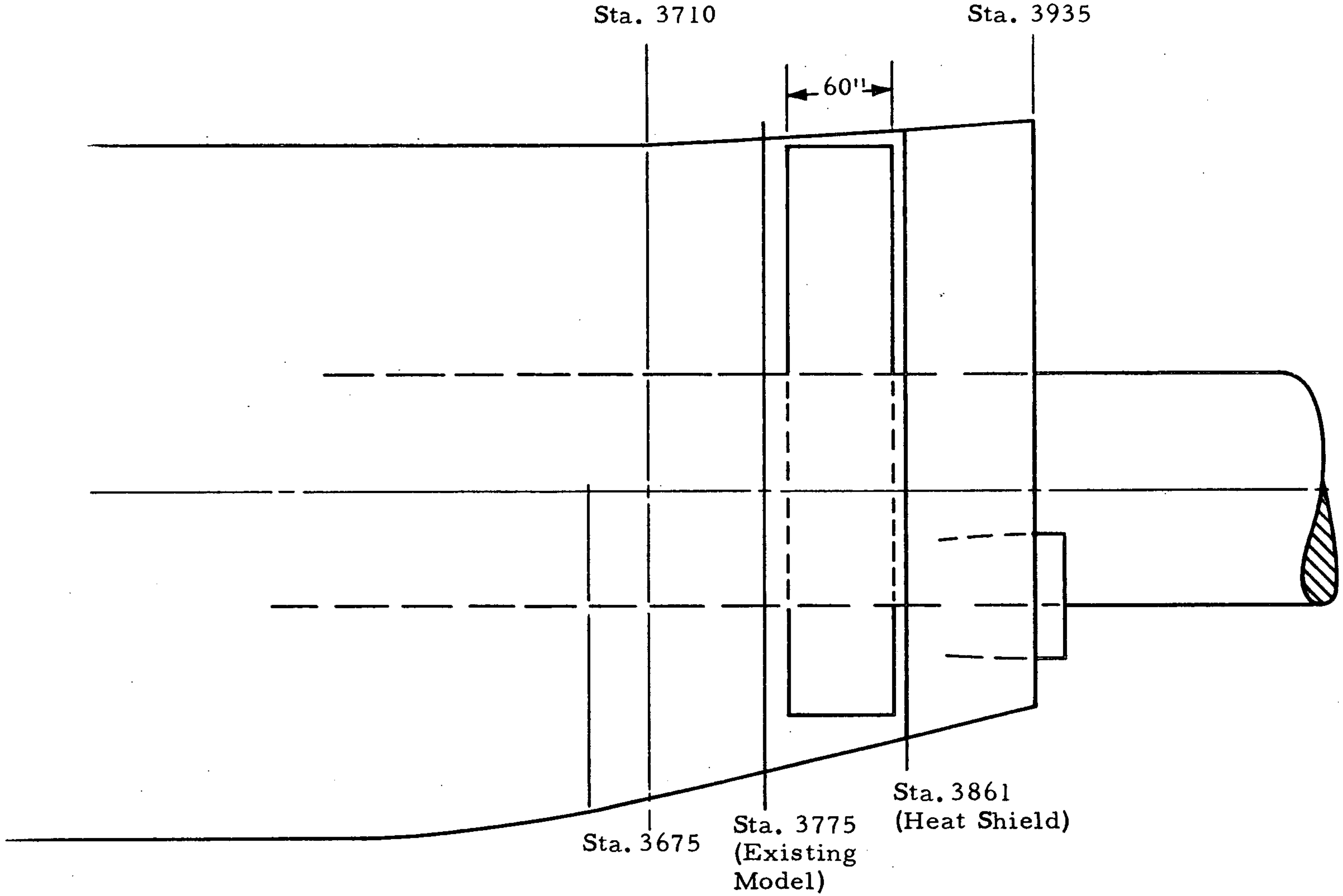


Fig. 11b - Flyback Booster Base Plenum Orifice Location (Side View)

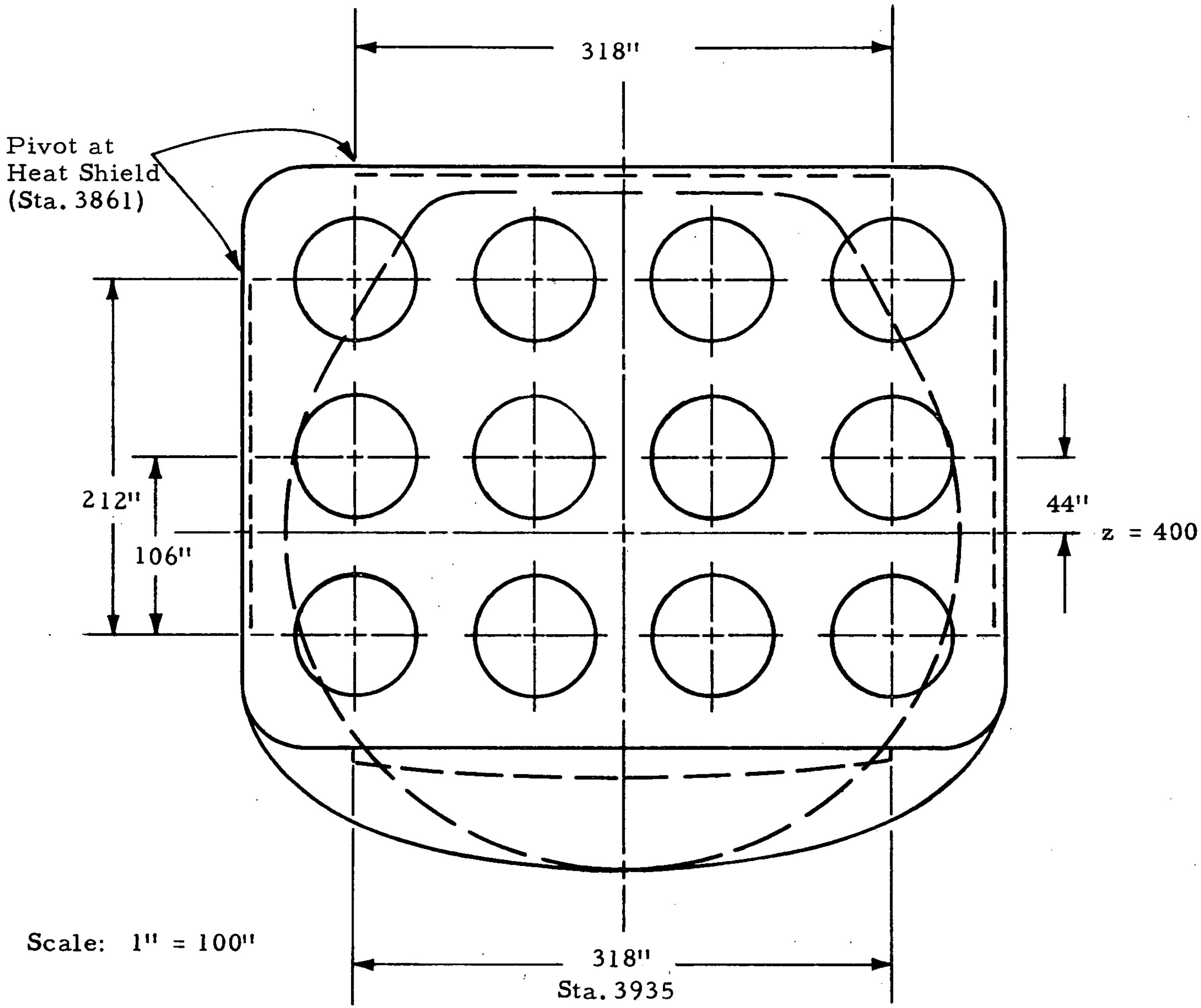


Fig. 12a - Flyback Booster Body Flaps (End View)

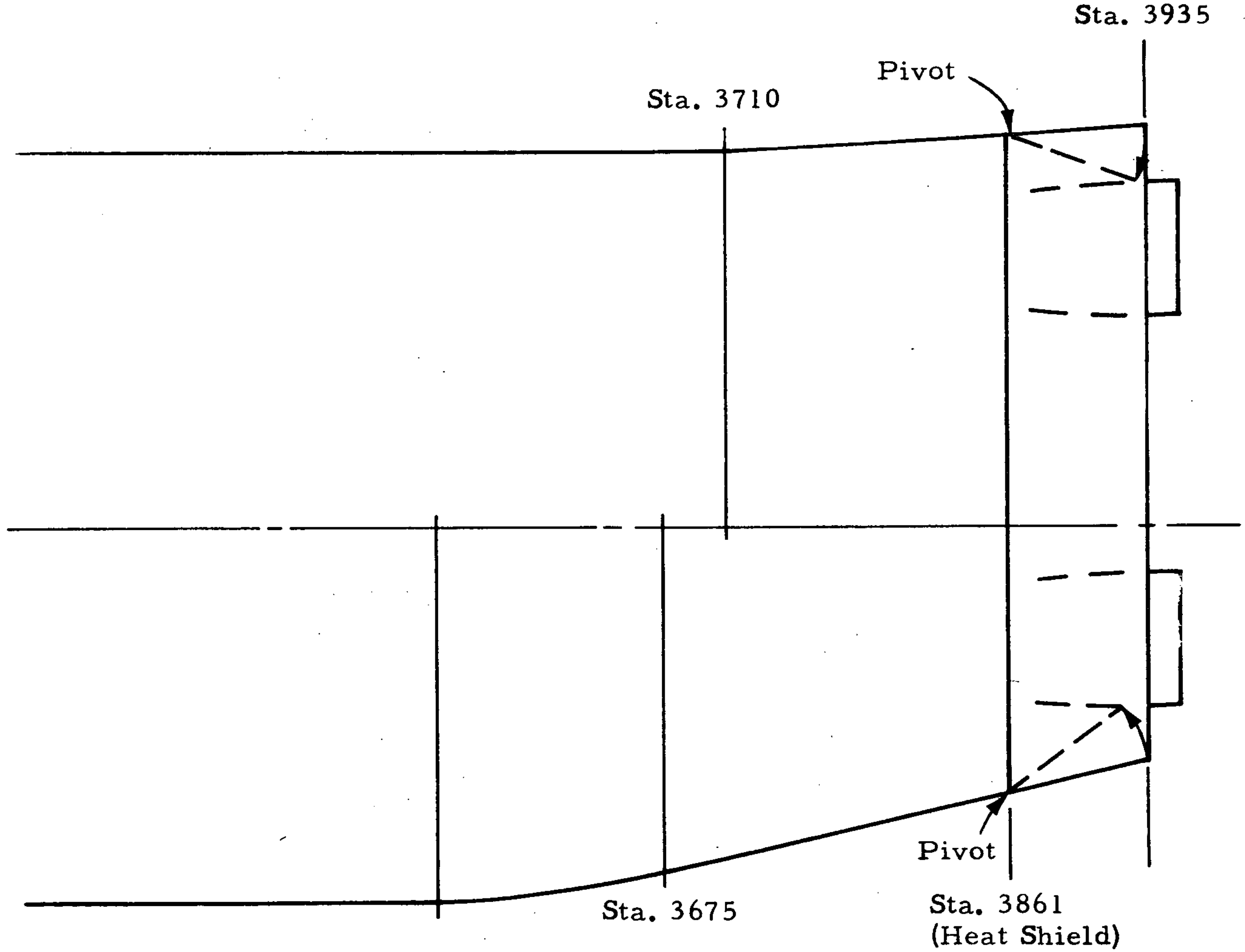


Fig. 12b - Flyback Booster Body Flaps (Side View)

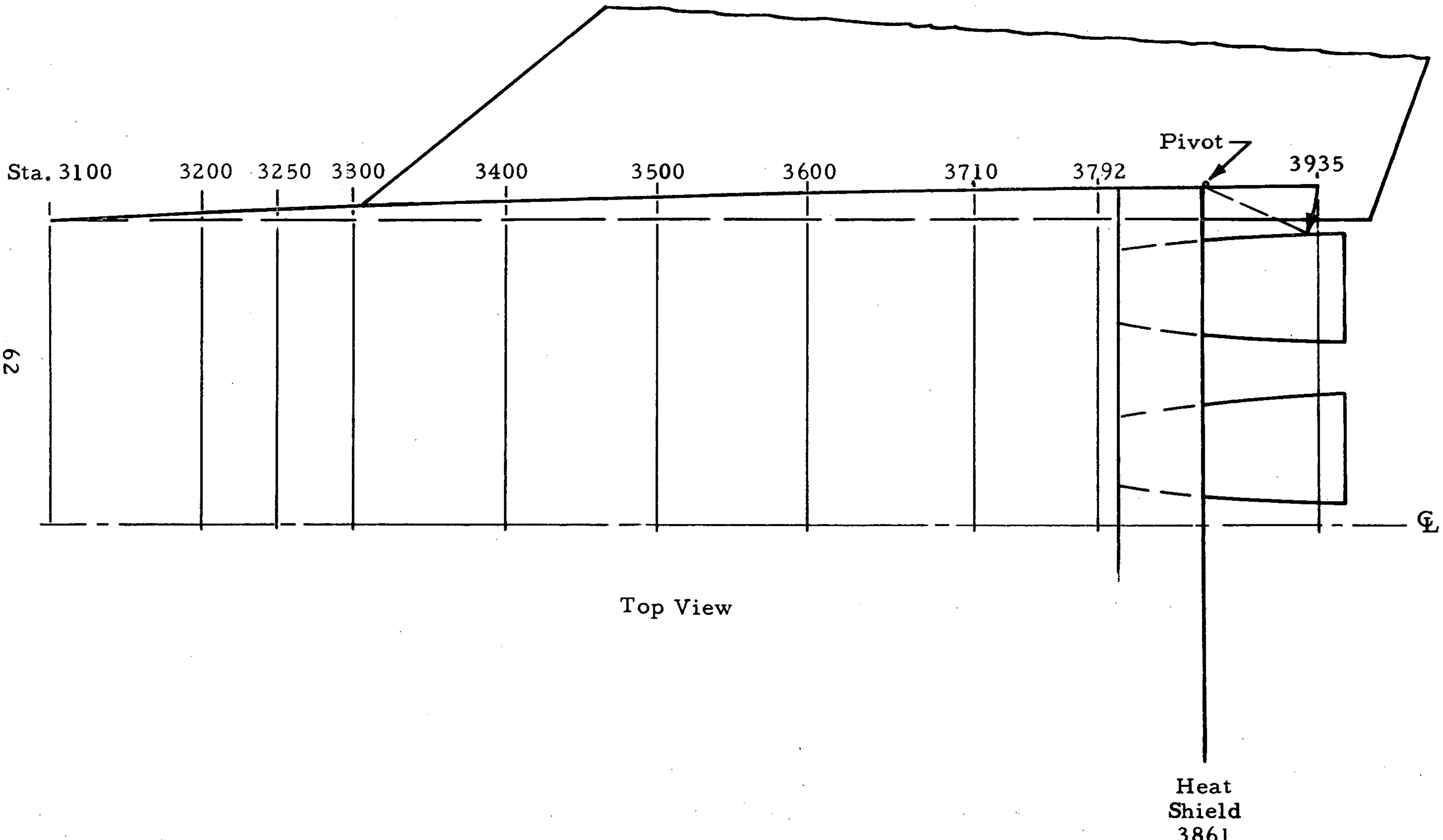


Fig. 12c - Flyback Booster Body Flaps (Top View)

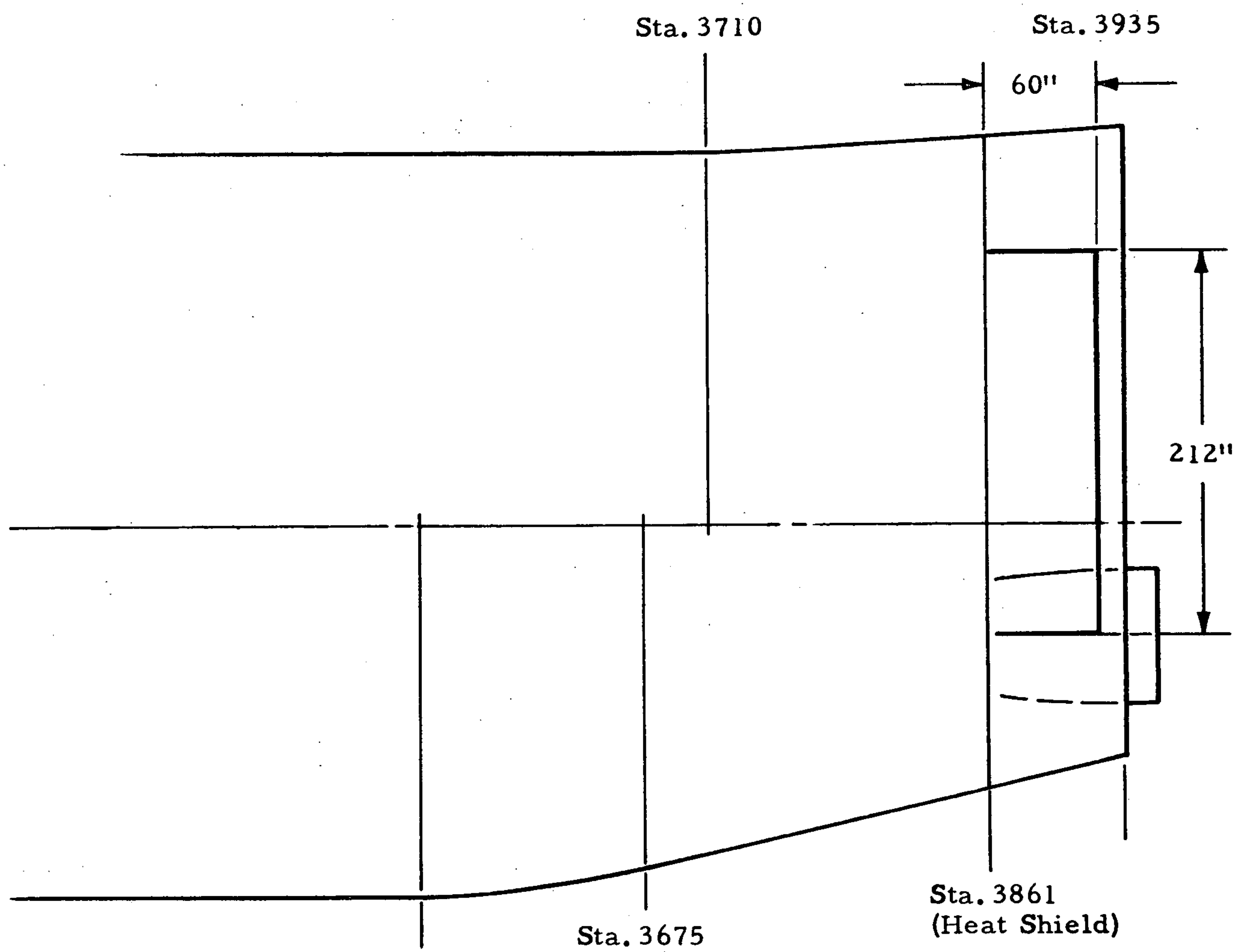


Fig. 13a - Flyback Booster Base Venting (Side View)

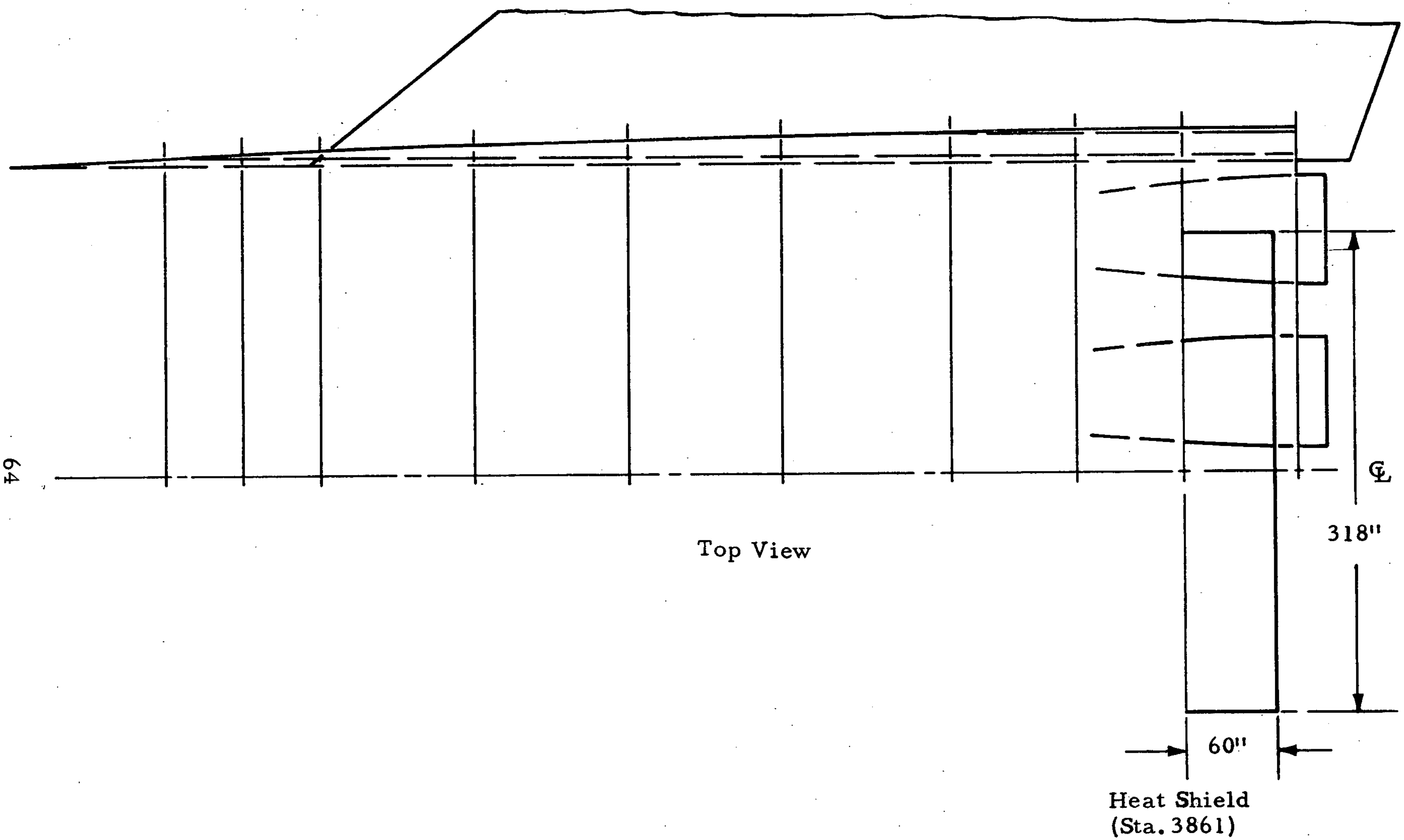


Fig. 13b - Flyback Booster Base Venting (Top View)

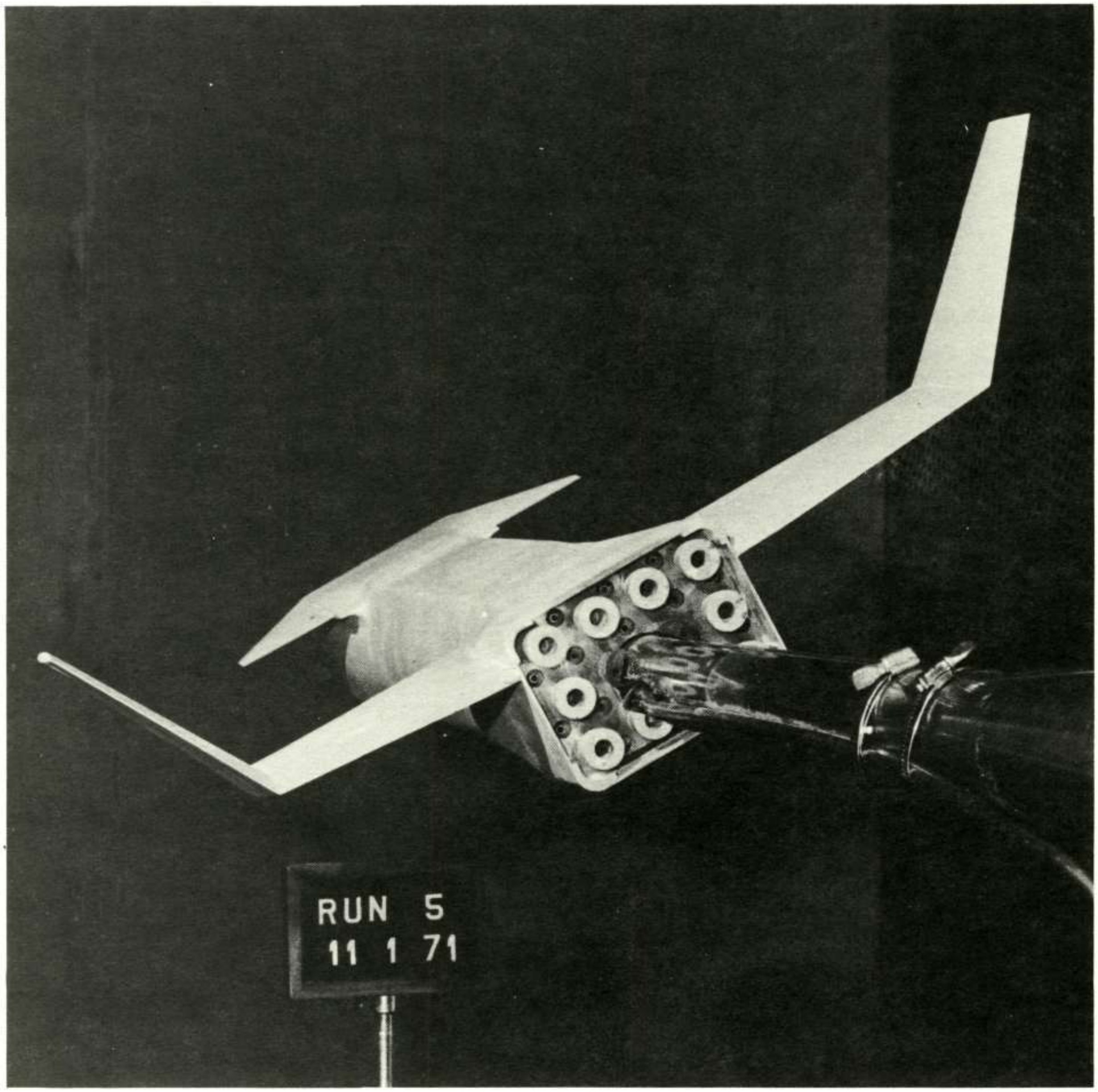


Fig. 14a - Installation Photograph, Flyback Booster Base Plenum
(CAL-T-18-063)

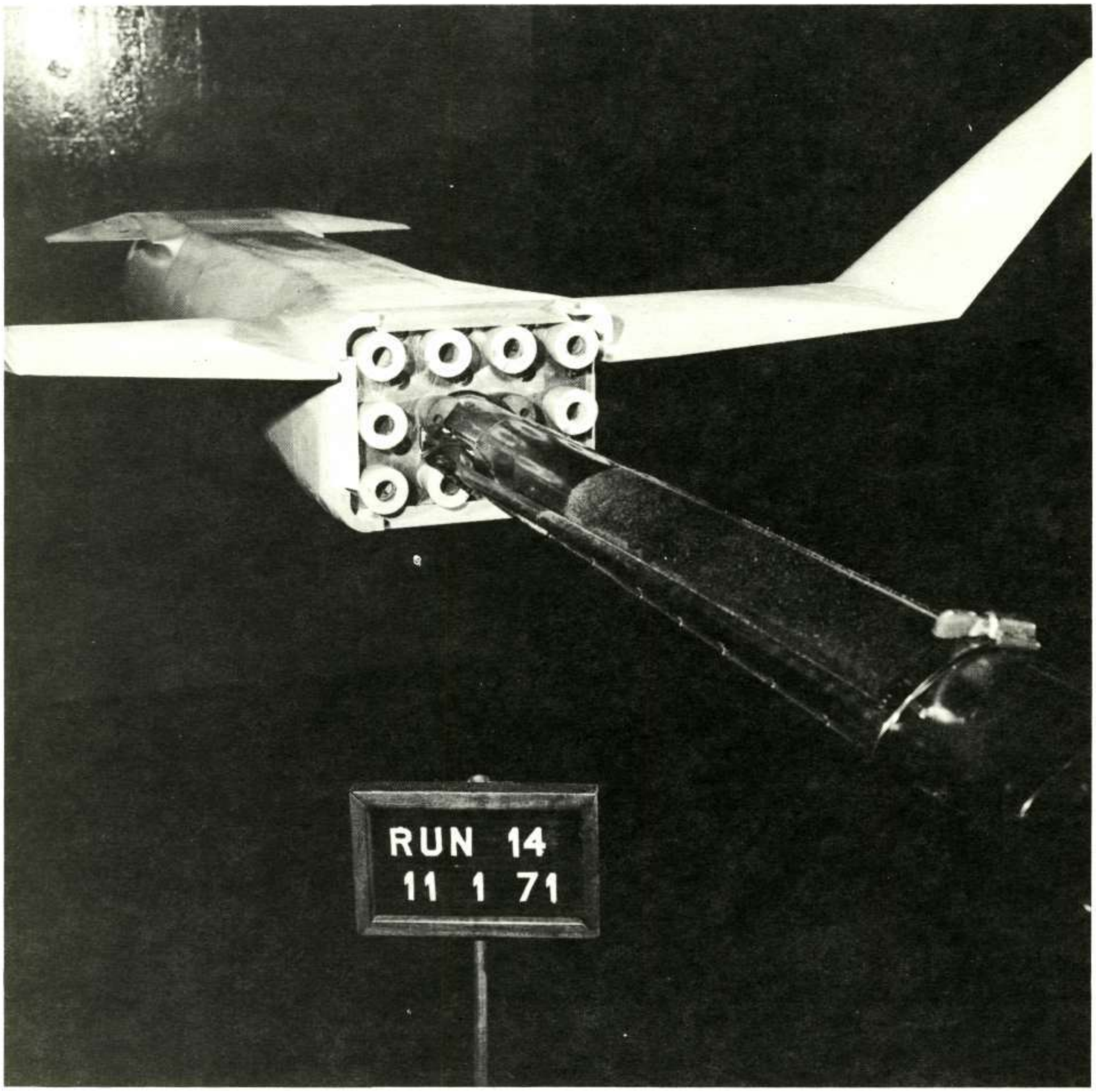


Fig. 14b - Installation Photograph, Flyback Booster Base Flaps (CAL-T-18-063)

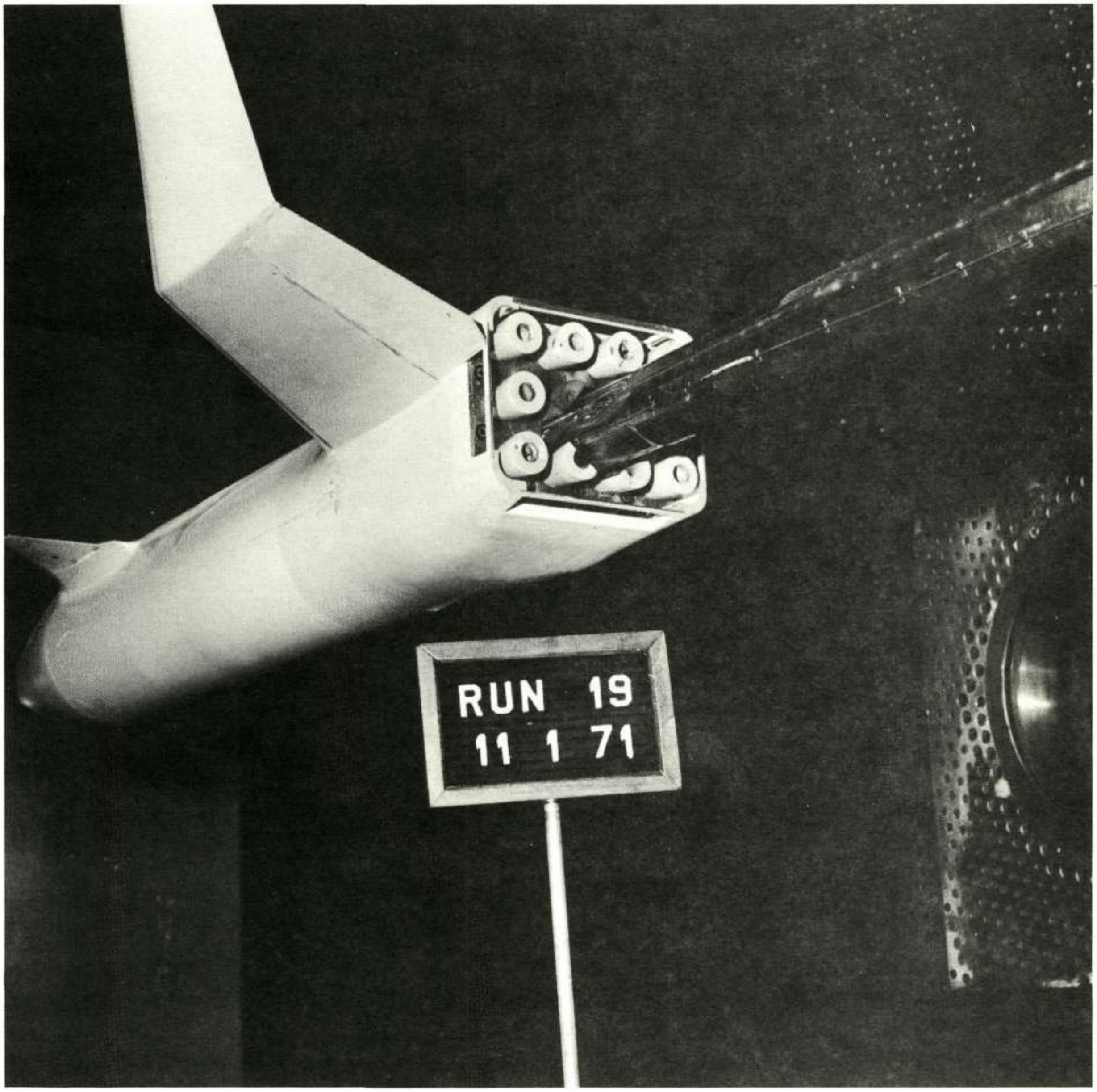


Fig. 14c - Installation Photograph, Flyback Booster Base Vent
(CAL-T-18-063)

2.5 STATIC STABILITY AND TRIM CHARACTERISTICS OF A 0.00227-SCALE PARAMETRIC PRESSURE-FED BOOSTER (TWT 526)

2.5.1 Test Purpose

Studies for a space shuttle launch configuration suggested that a large pressure-fed, water recoverable booster offered possible advantages. To determine the static aerodynamic characteristics of such a configuration a parametric test was conducted. Model parameters included nosecone angle, body length, body flare angle and fin size. Tunnel parameters included Mach numbers of 1.96, 2.74 and 4.96, angles of attack from 50 to 90 degrees, and angles of sideslip from -10 to 10 degrees while at an angle of attack of 60 degrees. A pretest report for this study was published in January 1972 (Ref. 6).

2.5.2 Test Facility

The test was conducted in the MSFC 14 x 14-Inch Trisonic Wind Tunnel. For a description of this facility see Section 2.1.2.

2.5.3 Model Description

The model included three nose cones, three body lengths, three base flare angles and three sets of fins. A maximum of 136 combinations can be created using these model parts. Figure 15 shows the dimensions of the various model parts. All model parts were made of aluminum. Figure 16 is a photograph of the associated model parts. Model nomenclature for the test was:

Symbol	Definition
C1	short cylindrical body (ℓ = 2.457 in)
C2	medium cylindrical body (ℓ = 3.357 in)
C3	long cylindrical body (ℓ = 4.257 in)

F0	straight flare extension (ℓ = 1.35 in)
F1	7.5-degree flare extension (ℓ = 1.35 in)
F2	15-degree flare extension (ℓ = 1.35 in)
F3	20-degree flare extension (ℓ = 1.35 in)
N1	25-degree nose cone (ℓ = 0.965 in)
N2	33-degree nose cone (ℓ = 0.693 in)
N3	40-degree nose cone (ℓ = 0.536 in)
T1	small tail fin (S_e = 0.848 in^2)
T2	medium tail fin (S_e = 1.696 in^2)
T3	large tail fin (S_e = 2.536 in^2)

Figure 17 shows the model as installed in the tunnel.

2.5.4 Data Reduction

Model forces and moments were measured by MSFC balances 201 and 227. Two balances were necessary because of the center of pressure shifts caused by running with fins on or off and varying normal force loads. Balance 201 was used for configurations and Mach numbers when loads were low, balance 227 was used for conditions when loads were high. In this manner maximum accuracy was obtained.

After correcting for sting deflections and weight tares, data were reduced to coefficient form by the use of the reference dimensions shown in Table 10. The moment reference point varied with configuration but was always at 60% of the body length. Actual distance of the moment reference point from the nose for each configuration is shown in Table 10.

Two methods were used for computing base axial force. The first method used a base pressure and a cavity pressure, while the second used only a base pressure. Areas used for base axial force computation are shown in Table 11.

The final coefficient data were entered into the SADSAC program and published as a data report (Ref. 26).

2.5.5 Discussion

Data that were obtained during this test represent a comprehensive study of high angle-of-attack supersonic aerodynamics for cone-cylinder-flare-fin configurations. Analysis of these data would provide design data useful for future studies of any vehicle of this type.

Table 12 shows the configurations run during the test. The study required 154 hours of wind tunnel test time to complete.

Table 10

0.00227-SCALE PARAMETRIC PRESSURE-FED BOOSTER REFERENCE DIMENSIONS

	Full Scale	Model Scale
Reference Area (S_{ref}) (Cylinder Cross-Sectional Area)	857 ft^2	0.636 in^2
Reference Length (ℓ_{ref}) and Span (b_{ref}) (Cylinder Diameter)	396 ft	0.900 in
Moment Reference Point (MRP) (0.60 ℓ_B Aft of Nose)		
N1 C1	1262 in	2.8650 in
N2 C1	1189 in	2.6994 in
N3 C2	1146 in	2.6022 in
N3 C2	1384 in	3.1416 in
N1 C3	1739 in	3.9468 in
N2 C3	1665 in	3.7806 in
N3 C3	1622 in	3.6828 in

Table 11

0.00227-SCALE PARAMETRIC PRESSURE-FED BOOSTER BASE AREAS

WITH CAVITY PRESSURE

Frustum	Full Scale Base Area (ft^2)	Full Scale Cavity Area (ft^2)	Model Scale Base Area (in^2)	Model Scale Cavity Area (in^2)
F0	334	523	0.248	0.388
F1	1080	523	0.801	0.388
F2	2121	523	1.574	0.388
F3	3023	523	2.243	0.388

WITHOUT CAVITY PRESSURE

Frustum	Full Scale Base Area (ft^2)	Model Scale Base Area (in^2)
F0	857	0.636
F1	1602	1.189
F2	2644	1.962
F3	3545	2.631

Table 12

RUN SCHEDULE FOR TWT 526

DATA SET IDENTIFIER	CONFIGURATION	SCHD. α	SCHD. β	PARAMETERS/VALUES θ_C	ℓ_{cr}	θ_F	S_T	NO. of RUNS	MACH NUMBERS (OR ALTERNATE INDEPENDENT VARIABLE) 1.96	2.74	4.96
	N1C1F0	D	0	25°	2.457	0°	0		✓	✓	✓
		E	0						✓	✓	✓
		60	A						✓	✓	✓
	N3C1F0	D	0	40°					✓	✓	✓
		E	0						✓	✓	✓
		60	A						✓	✓	✓
	N3C1F1	D	0			7.5°			✓	✓	✓
		E	0						✓	✓	✓
		60	A						✓	✓	✓
	N3C1F2	D	0			15°			✓	✓	✓
		E	0			15°			✓	✓	✓
	N1C1F3	D	0	25°		20°			✓	✓	✓
		E	0						✓	✓	✓
		60	A						✓	✓	✓
	N3C1F3	D	0	40°					✓	✓	✓
		E	0						✓	✓	✓
		60	A						✓	✓	✓
	N3C1F0T1	D	0			0°	.424		✓	✓	✓
		E	0						✓	✓	✓
		60	A						✓	✓	✓

1 7 13 19 25 31 37 43 49 55 61 67 75 76

COEFFICIENTS: IDPVAR(1) | IDPVAR(2) | NDV

α or β SCHEDULES

α: D = 50° to 70° by Δα = 2° ; E = 70° to 90° by Δα = 2°

β: A = -10° to 10° by Δα = 2°

Table 12 (Continued)

DATA SET IDENTIFIER	CONFIGURATION	SCHD. α	SCHD. β	θ_c	ℓ_{cr}	θ_F	S_T	NO. of RUNS	1.96	2.74	4.96
	N3C1F0T2	D	0	40°	2.457	0°	.848		✓	✓	✓
		E	0						✓	✓	✓
		60	A						✓	✓	✓
	N3C1F0T3	D	0				1.272		✓	✓	✓
		E	0						✓	✓	✓
		60	A						✓	✓	✓
	N3C2F0	D	0		3.357		0		✓	✓	✓
		E	0						✓	✓	✓
		60	A						✓	✓	✓
	N3C2F3	D	0			20°			✓	✓	✓
		E	0						✓	✓	✓
		60	A						✓	✓	✓
	N1C3F0	D	0	25°	4.257	0°			✓	✓	✓
		E	0						✓	✓	✓
		60	A						✓	✓	✓
	N3C3F0	D	0	40°					✓	✓	
		E	0						✓	✓	
		60	A						✓	✓	✓
	N3C3F1	D	0			7.5°			✓	✓	✓
		E	0			7.5°			✓	✓	✓

1 7 13 19 25 31 37 43 49 55 61 67 75 76

IDPVAR(1) | IDPVAR(2) | NDV

COEFFICIENTS:

α or β SCHEDULES

α: D = 50° to 70° by Δα = 2° ; E = 70° to 90° by Δα = 2°

β: A = -10° to 10° by Δβ = 2°

Table 12 (Continued)

DATA SET IDENTIFIER	CONFIGURATION	SCHD. α	SCHD. β	PARAMETERS/VALUES θ_C	ℓ_{CY}	θ_F	S_T	NO. of RUNS	MACH NUMBERS (OR ALTERNATE INDEPENDENT VARIABLE) 1.96	2.74	4.96
	N3C3F1	60	A	40°	4.257	7.5°	0		✓	✓	✓
	N3C3F2	D	0	↓	↓	15°	↓		✓	✓	✓
	↓	E	↓			15°			✓	✓	✓
	N1C3F3	D		25°		20°			✓	✓	✓
	↓	E	↓			↓			✓	✓	✓
	↓	60	A	↓					✓	✓	✓
	N2C3F3	D	0	33°					✓	✓	✓
	↓	E	0	↓					✓	✓	✓
	↓	60	A	↓					—	—	—
	N3C3F3	D	0	40°					✓	✓	
	↓	E	0	↓					✓	✓	
	↓	60	A			↓	↓		✓	✓	✓
	N3C3F0T1	D	0			0°	0.424		✓	✓	✓
	↓	E	0			↓	↓		✓	✓	✓
	↓	60	A				↓		✓	✓	✓
	N3C3F0T2	D	0				0.848		✓	✓	✓
	↓	E	0				↓		✓	✓	✓
	↓	60	A				↓		✓	✓	✓
	N3C3F0T3	D	0				1.272		✓	✓	
	↓	E	0	↓	↓	↓	1.272		✓	✓	

1 7 13 19 25 31 37 43 49 55 61 67 75 76

IDPVAR(1) | IDPVAR(2) | NDV

COEFFICIENTS:

α or β SCHEDULES

α: D = 50° to 70° by Δα = 2° ; E = 50° to 70° by Δα = 2°

β: A = -10° to 10° by Δβ = 2°

Table 12 (Continued)

DATA SET IDENTIFIER	CONFIGURATION	SCHD. α	SCHD. β	PARAMETERS/VALUES θ_C	ℓ_{CY}	θ_F	S_T	NO. of RUNS	MACH NUMBERS (OR ALTERNATE INDEPENDENT VARIABLE) 1.96	2.74	4.96
	N3C3F0T3	60	A	40°	4.267	0°	1.272		✓	✓	✓
	N1C1T1	D	0	25°	2.457	7.5°	↓		✓		
	↓	E	0	↓	↓	↓	↓				
	↓	60	A	↓	↓	↓	↓		✓		
	N2C1F0	D	0	33°	↓	0°	↓		✓	✓	✓
	↓	E	0	↓	↓	↓	↓		✓	✓	✓
	↓	60	A	↓	↓	↓	↓				
	N2C1F3	D	0	↓	↓	20°	↓		✓	✓	✓
	↓	E	0	↓	↓	↓	↓		✓	✓	✓
	↓	60	A	↓	↓	↓	↓				
	N3C1F1T2	D	0	40°	↓	7.5°	.848		✓	✓	✓
	↓	E	0	↓	↓	↓	↓		✓	✓	✓
	↓	60	A	↓	↓	↓	↓		✓	✓	✓
	N3C1F1T1	D	0	↓	↓	↓	.424		✓	✓	✓
	↓	E	0	↓	↓	↓	↓		✓	✓	✓
	↓	60	A	↓	↓	↓	↓		✓	✓	✓
	N3C1F1T3	D	0	↓	↓	↓	1.272		✓	✓	✓
	↓	E	0	↓	↓	↓	↓			✓	✓
	↓	60	A	↓	↓	↓	↓		✓	✓	✓
	N3C2F1	D	0	↓	3.357	↓	0		✓	✓	✓

1 7 13 19 25 31 37 43 49 55 61 67 75 76

→ IDPVAR(1) | IDPVAR(2) | NDV

COEFFICIENTS:

α or β SCHEDULES

α: D = 50° to 70° by Δα = 2°; E = 70° to 90° by Δα = 2°

β: A = -10° to 10° by Δβ = 2°

Table 12 (Continued)

DATA SET IDENTIFIER	CONFIGURATION	SCHD. α	SCHD. β	PARAMETERS/VALUES θ_c	l_{cr}	θ_F	S_T	NO. of RUNS	MACH NUMBERS (OR ALTERNATE INDEPENDENT VARIABLE) 1.96	2.74	4.96
	N3C2F1	E	0	40°	3.357	7.5°	0		✓	✓	✓
	↓	60	A	↓	↓	↓	↓		✓	✓	✓
	N3C2F0T2	D	0			0°	.848		✓	✓	✓
		E	0						✓	✓	✓
	↓	60	A				↓		✓	✓	✓
	N3C2F0T1	D	0				.424		✓	✓	✓
		E	0						✓	✓	✓
	↓	60	A			↓			✓	✓	✓
	N3C2F1T1	D	0			7.5°			✓	✓	✓
		E	0						✓	✓	✓
	↓	60	A				↓		✓	✓	✓
	N3C2F1T2	D	0				.848		✓	✓	✓
		E	0						✓	✓	✓
	↓	60	A			↓	↓		✓	✓	✓
	N3C2F0T3	D	0			0°	1.272		✓	✓	✓
		E	0						✓	✓	✓
	↓	60	A			↓			✓	✓	✓
	N3C2F1T3	D	0			7.5°			✓	✓	✓
		E	0						✓	✓	✓
	↓	60	A	↓	↓	↓	↓		✓	✓	✓

1 7 13 19 25 31 37 43 49 55 61 67 75 76

COEFFICIENTS: → IDPVAR(1) | IDPVAR(2) | NDV

α or β SCHEDULES

α: D = 50° to 70° by Δα = 2°; E = 70° to 90° by Δα = 2°

β: A = -10° to 10° by Δβ = 2°

Table 12 (Concluded)

DATA SET IDENTIFIER	CONFIGURATION	SCHD. α	SCHD. β	PARAMETERS/VALUES θ_c	ℓ_{cr}	θ_F	S_T	NO. of RUNS	MACH NUMBERS (OR ALTERNATE INDEPENDENT VARIABLE) 1.96	2.74	4.96									
	N2C3F0	D	0°	33°	4.257	0°	0		✓	✓	✓									
		E	0°						✓	✓	✓									
		60°	A						✓	✓	✓									
	N3C3F1T1	D	0°	40°		7.5°	.424			✓	✓									
		E	0°							✓	✓									
		60°	A						✓	✓	✓									
	N3C3F1T2	D	0°				.848			✓	✓									
		E	0°							✓	✓									
		60°	A						✓	✓	✓									
	N3C3F1T3	D	0°				1.272			✓										
		E	0°							✓										
		60°	A						✓	✓	✓									
	N3C3F0 + T.S.	D	0°			0°	0			✓										
		E					0			✓										
	N3C3F0T3 + T.S.	D					1.272			✓										
		E					1.272			✓										

1 7 13 19 25 31 37 43 49 55 61 67 75 76

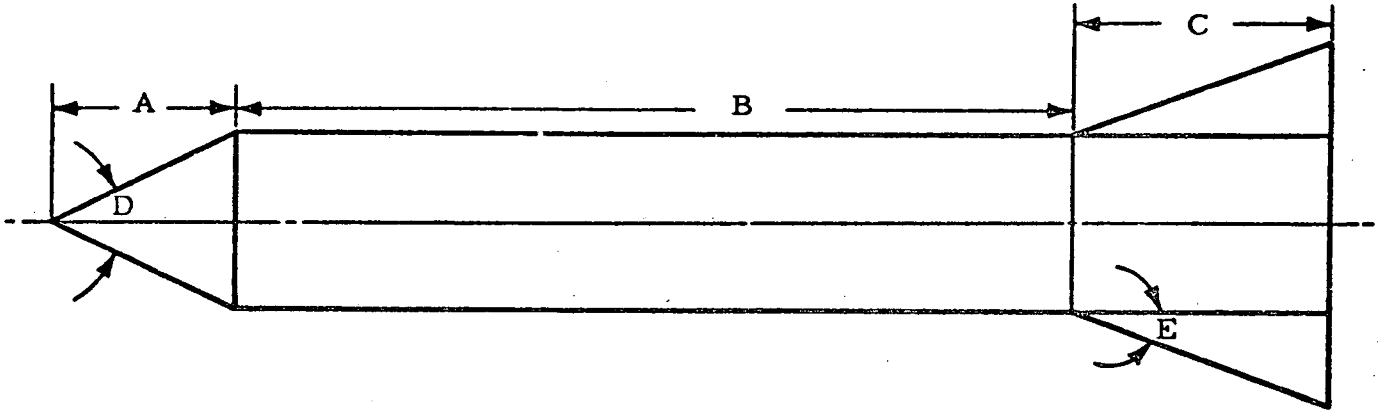
COEFFICIENTS: → IDPVAR(1) | IDPVAR(2) | NDV

α or β SCHEDULES

α: D = 50° to 70° by $\Delta\alpha = 2°$; E = 70° to 90° by $\Delta\alpha = 2°$

β: A = -10° to 10° by $\Delta\beta = 2°$

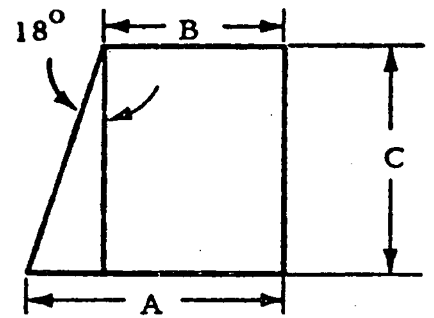
NOTE: All dimensions in inches (Model Scale)



A		B		C		D (deg)		E (deg)	
N1	.9648	C1	2.457	F0	1.35	N1	50	F0	0
N2	.6929	C2	3.357	F1	1.35	N2	66	F1	7.5
N3	.5363	C3	4.257	F2	1.35	N3	80	F2	15
				F3	1.35			F3	20

Fig. 15 - 0.00227-Scale Parametric Pressure-Fed Booster Model Geometry
(a) Cones, Cylinders and Flares

Planform View of Fin



NOTE: All dimensions in inches (Model Scale)

Fin	A	B	C
T1	0.691	0.45	0.743
T2	0.868	0.45	1.287
T3	1.013	0.45	1.734

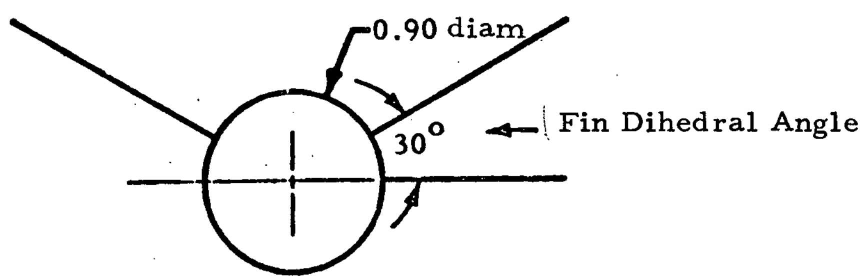


Fig. 15 (Concluded)
(b) Fins

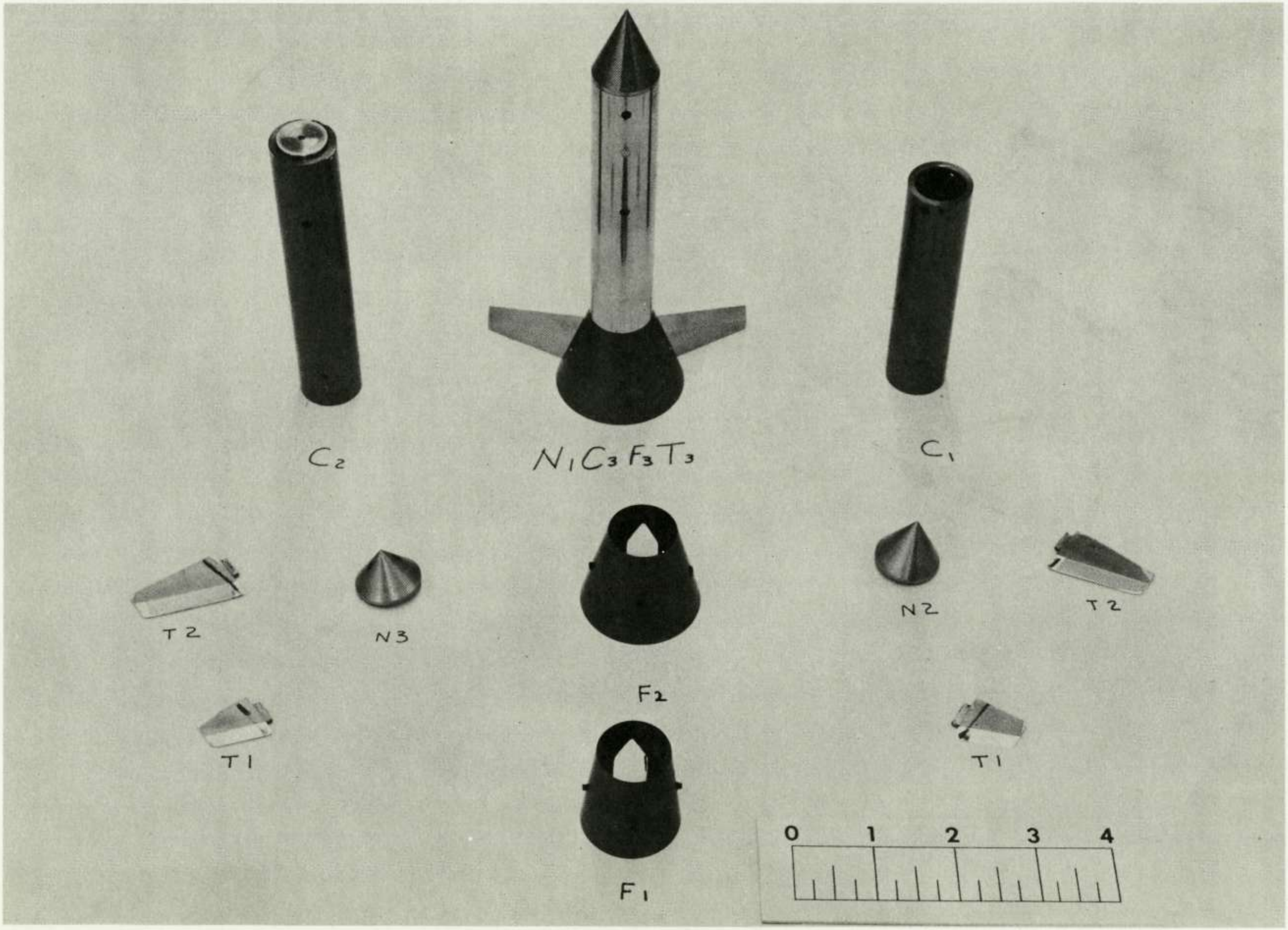


Fig. 16 - 0.00227-Scale Parametric Pressure-Fed Booster Model Parts

Fig. 17a - Installation Photograph, Pressure-Fed Booster (TWT 526)

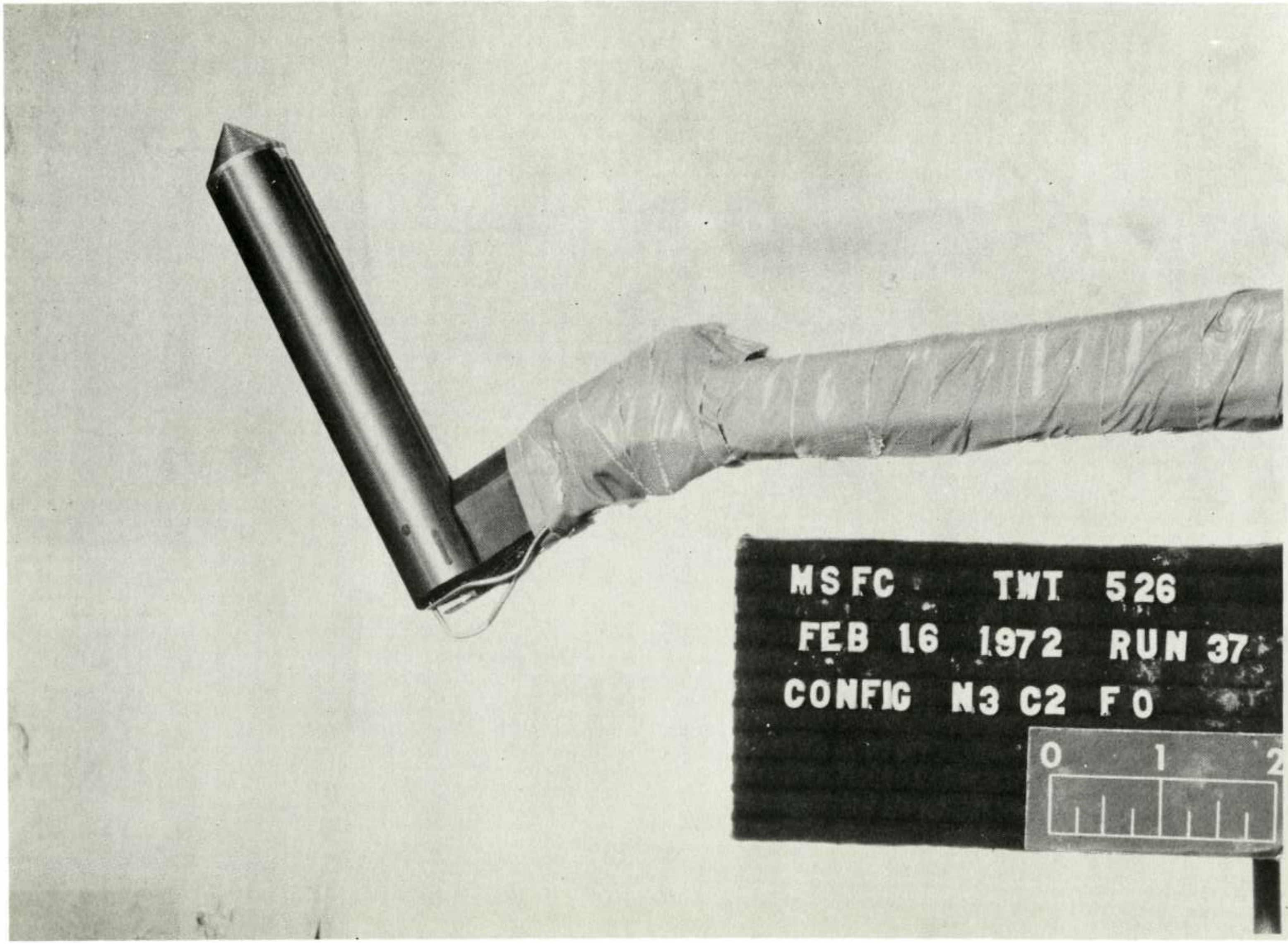


Fig. 17b - Installation Photograph, Pressure-Fed Booster (TWT 526)

2.6 REENTRY STUDY OF A 0.00513-SCALE SOLID ROCKET BOOSTER (TWT 541)

2.6.1 Test Purpose

The current space shuttle concept calls for the solid rocket boosters to be recovered for reuse. The purpose of this test was to give preliminary information on the booster aerodynamic characteristics so that recovery techniques might be devised.

Upon separation the booster follows a ballistic trajectory. Since separation will be made with no particular regard to booster attitude, the booster may well be tumbling upon reentry. To measure the effect of all possible reentry attitudes, the model was tested at angles of attack from -10 to 190 degrees. A range of Mach numbers from .6 to 4.96 was covered for the test. The nozzle was tested in three different roll positions. A pretest report for this study was published in April 1972 (Ref. 7).

2.6.2 Test Facility

The test was conducted in the MSFC 14 x 14-Inch Trisonic Wind Tunnel. For a description of this tunnel see Section 2.1.2.

2.6.3 Model Description

The model is a 0.00513-scale version of a 156-inch solid rocket booster. Figure 18 shows general arrangements of the model. To test the model for the wide range of angles of attack, special mounting arrangements had to be provided. Figure 19 shows the mounting systems used to provide the full angle of attack range. Figure 20 shows the model installed in the tunnel.

The model is constructed entirely of stainless steel. Model design was done by MSFC. Model nomenclature for the test was:

Symbol	Definition
B1	body
N1	full nose (α = -10 to 130 deg)
N2	cut nose (α = 130 to 190 deg)
E1	cut rocket nozzle (α = -10 to 50 deg
S1	one caliber strake with 0-deg dihedral angle, located at 0-deg with respect to the side of the body
S2A	two caliber strake with 15-deg dihedral angle, located at 0-deg with respect to the side of the body
S2B	identical to S2A except has 30-deg dihedral
S3B	same as S2A except has 0-deg dihedral

2.6.4 Data Reduction

Model forces and moments were measured using MSFC balance 201. All forces and moments were reduced to coefficient form by use of the reference dimensions shown in Table 13. Data were corrected for sting deflections and weight tares.

The data were entered in the Chrysler SADSAC program, and published as a data report (Ref. 27).

2.6.5 Discussion

Configurations tested are shown in Table 14. The test was straightforward with few problem areas. Data discrepancies existed in the form of shifts when the straight sting mounting system (α = -10 to 50° and 130 to 190°) was changed to the dogleg mounting system (α = 50 to 90° and 90 to 130°) and when the nose and nozzle were interchanged on the dogleg mount. The discrepancies are believed to be caused by the cutouts in the model to accomodate

the mounting systems in the case of the pitch plane data and due to model-balance misalignment or a possible tunnel crossflow angularity problem in the case of yaw plane data. The test required 140 hours of wind tunnel occupancy time to complete.

Table 13

0.00513-SCALE 156-INCH SRM REFERENCE DIMENSIONS

Parameter	Full Scale	Model Scale
Reference Area (S_{ref})	19104 in^2	0.503 in^2
Reference Length (ℓ_{ref})	156 in.	0.8 in.
Reference Span (b_{ref})	156 in.	0.8 in.
Balance Location (from body base)		
α = -10° to 50°	—	3.213 in.
α = 50° to 90°	—	3.213 in.
α = 90° to 130°	—	4.213 in.
α = 130° to 190°	—	3.213 in.
Moment Reference Center (from body base)		
α = -10° to 50°	645 in.	3.310 in.
α = 50° to 90°	645 in.	3.310 in.
α = 90° to 130°	869 in.	4.456 in.
α = 130° to 190°	869 in.	4.456 in.
Base Area (A_b)		0.503 in^2
Nozzle Area (A_1)		.052 in^2
(A_2)		.173 in^2

Table 14

RUN SCHEDULE FOR TWT 541

DATA SET IDENTIFIER	CONFIGURATION	SCHD. α	SCHD. β	PARAMETERS/VALUES φ				NO. of RUNS	MACH NUMBERS (OR ALTERNATE INDEPENDENT VARIABLE) 0.6	0.9	1.1	1.2	1.46	1.96	2.99	4.00				
	N1B1E1	A	0	0°					✓	✓	✓	✓	✓	✓	✓	✓				
				90°					✓	✓		✓		✓		✓				
				-90°					✓	✓		✓		✓		✓				
				45°					✓	✓		✓		✓		✓				
		B		0°					✓	✓	✓	✓	✓	✓	✓	✓				
				90°					✓	✓		✓		✓		✓				
				-90°					✓	✓		✓		✓		✓				
				45°					✓	✓		✓		✓		✓				
		20°	A	0°					✓	✓		✓		✓		✓				
		C	0°						✓	✓	✓	✓	✓	✓	✓	✓				
	N2B1E2	H							✓	✓	✓	✓	✓	✓	✓	✓				
		I							✓	✓	✓	✓	✓	✓	✓	✓				
				90°					✓	✓		✓		✓		✓				
				-90°					✓	✓		✓		✓		✓				
				45°					✓	✓		✓		✓		✓				
		160°	A	0°					✓	✓		✓		✓		✓				
		J	0	0°					✓	✓	✓	✓	✓	✓	✓	✓				
				90°					✓	✓		✓		✓		✓				
				-90°					✓	✓		✓		✓		✓				
				45°					✓	✓		✓		✓		✓				

1 7 13 19 25 31 37 43 49 55 61 67 75 76

COEFFICIENTS: IDPVAR(1) | IDPVAR(2) | NDV

α or β SCHEDULES

α: A = -10° to 10° by Δα = 2°; B = 10° to 30° by Δα = 5°; C = 30° to 60° by Δα = 5°

H = 130° to 150° by Δα = 5°; I = 150° to 170° by Δα = 5°; J = 170° to 190° by Δα = 2°

β: A = -10° to 10° by Δβ = 5°

Table 14 (Continued)

DATA SET IDENTIFIER	CONFIGURATION	SCHD. α	SCHD. β	PARAMETERS/VALUES φ				NO. of RUNS	0.6	0.9	1.1	1.2	1.46	1.96	2.99	4.00				
	N1 B1 E2	D	0°	0°					✓	✓	✓	✓	✓	✓	✓	✓				
				90°					✓	✓		✓		✓		✓				
				-90°					✓	✓		✓		✓		✓				
				45°					✓	✓		✓		✓		✓				
		60	A	0°					✓	✓		✓		✓		✓				
		80	A						✓	✓		✓		✓		✓				
		E	0						✓	✓	✓	✓	✓	✓	✓	✓				
				90°					✓	✓		✓		✓		✓				
				-90°					✓	✓		✓		✓		✓				
				45°					✓	✓		✓		✓		✓				
		F		0°					✓	✓	✓	✓	✓	✓	✓	✓				
				90°					✓	✓		✓		✓		✓				
				-90°					✓	✓		✓		✓		✓				
				45°					✓	✓		✓		✓		✓				
		100	A	0°					✓	✓		✓		✓		✓				
		120	A						✓	✓		✓		✓		✓				
		G	0						✓	✓	✓	✓	✓	✓	✓	✓				
				90°					✓	✓		✓		✓		✓				
				-90°					✓	✓		✓		✓		✓				
				45°					✓	✓		✓		✓		✓				

MACH NUMBERS (OR ALTERNATE INDEPENDENT VARIABLE)

1 7 13 19 25 31 37 43 49 55 61 67 75 76

COEFFICIENTS: → IDPVAR(1) | IDPVAR(2) | NDV

α or β SCHEDULES

α: D = 50° to 70° by Δα = 5°; E = 70° to 80° by Δα = 5° and 80° to 90° by Δα = 2°

F = 90° to 100° by Δα = 2° and 100° to 110° by Δα = 5°; G = 110° to 180° by Δα = 5°

β: A = -10° to 10° by Δβ = 5°

Table 14 (Concluded)

DATA SET IDENTIFIER	CONFIGURATION	SCHD. α	SCHD. β	PARAMETERS/VALUES φ	Γ_{STK}	STK LOC		NO. of RUNS	0.6	0.9	1.1	1.2	1.46	1.96	2.99	4.00				
	N2B1E2+Trip Strip	I	0	0°	–	–			✓	✓		✓								
	↓ Hysteresis	K	0	↓	↓	↓			✓	✓		✓								
	N1B1E2	D	↓	↓	↓	↓										✓				
	↓	E		↓	↓	↓										✓				
	↓	E		↓	↓	↓										✓				
	↓	D		↓	↓	↓										✓				
	N1B1	D		–	↓	↓										✓				
	N1B1	E		–	↓	↓										✓				
	N1B1E2S1	↓		90°	0°	0°			✓			✓		✓		✓				
90	N1B1E2S2C	↓		↓	↓	0°			✓			✓		✓		✓				
	↓	↓		↓	↓	15°			✓			✓		✓		✓				
	↓	↓		↓	↓	30°			✓			✓		✓		✓				
	N1B1E2S2A	↓		↓	15°	0°			✓			✓		✓		✓				
	N1B1E2S2B	↓		↓	30°	0°			✓			✓		✓		✓				
	N1B1E2	↓	↓	↓	–	↓			✓			✓		✓		✓				
	↓	F	↓	↓	–	↓			✓			✓		✓		✓				

1 7 13 19 25 31 37 43 49 55 61 67 75 76

COEFFICIENTS: → IDPVAR(1) | IDPVAR(2) | NDV

α or β SCHEDULES

α: D = 50° to 70° by Δα = 5° ; E = 70° to 80° by Δα = 5° and 80° to 90° by Δα = 2°

F = 90° to 100° by Δα = 2° and 100° to 110° by Δα = 2° ; I = 150° to 170° by Δα = 5°

K = 150° to 130° by Δα = 5°

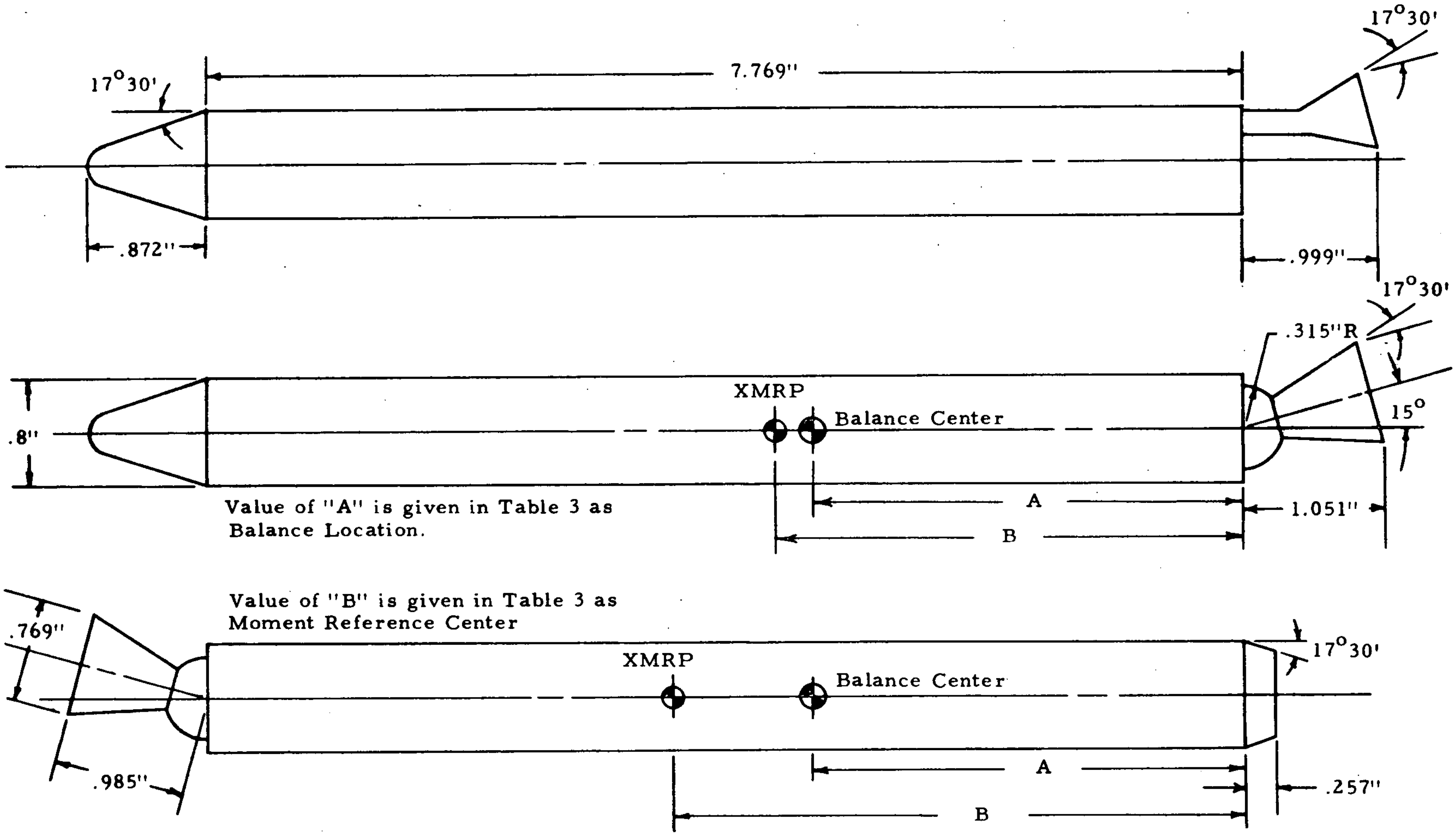


Fig. 18a - General Arrangement, 0.00513-Scale 156-Inch Solid Rocket Motor Geometry

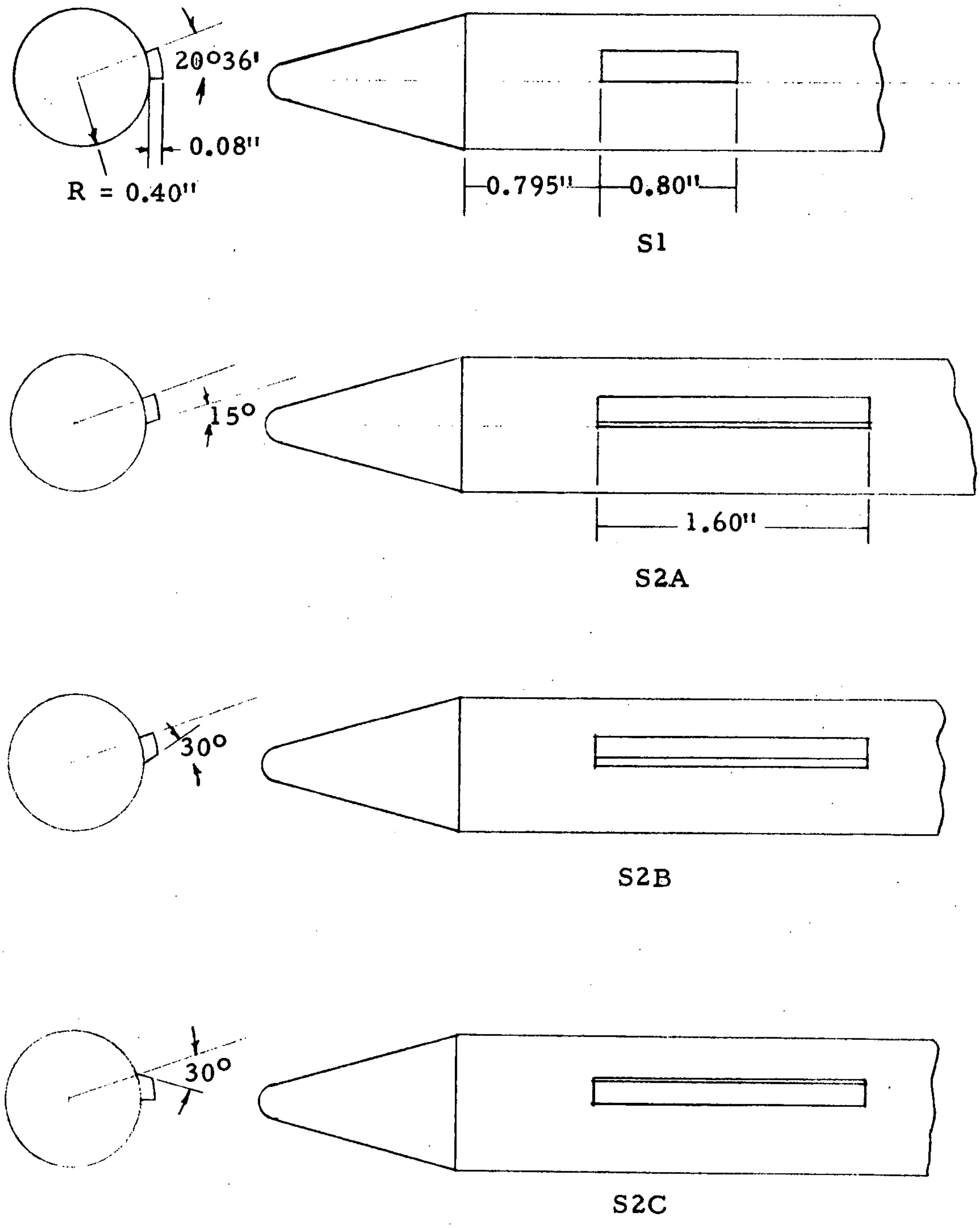


Fig. 18b – Strake Geometry

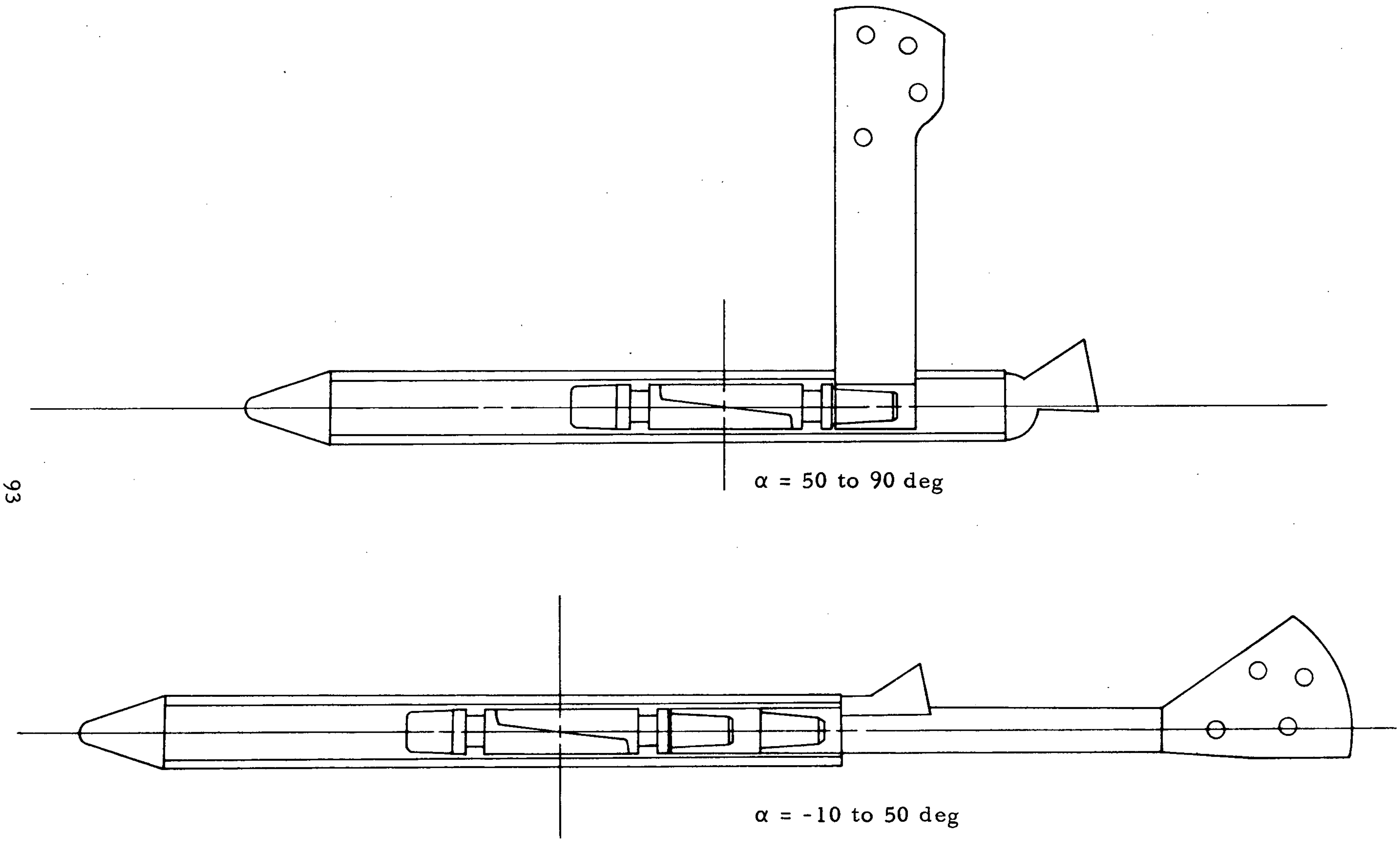


Fig. 19a - Mounting Arrangements for 156-Inch SRM, Angle of Attack-10 to 90 Degrees

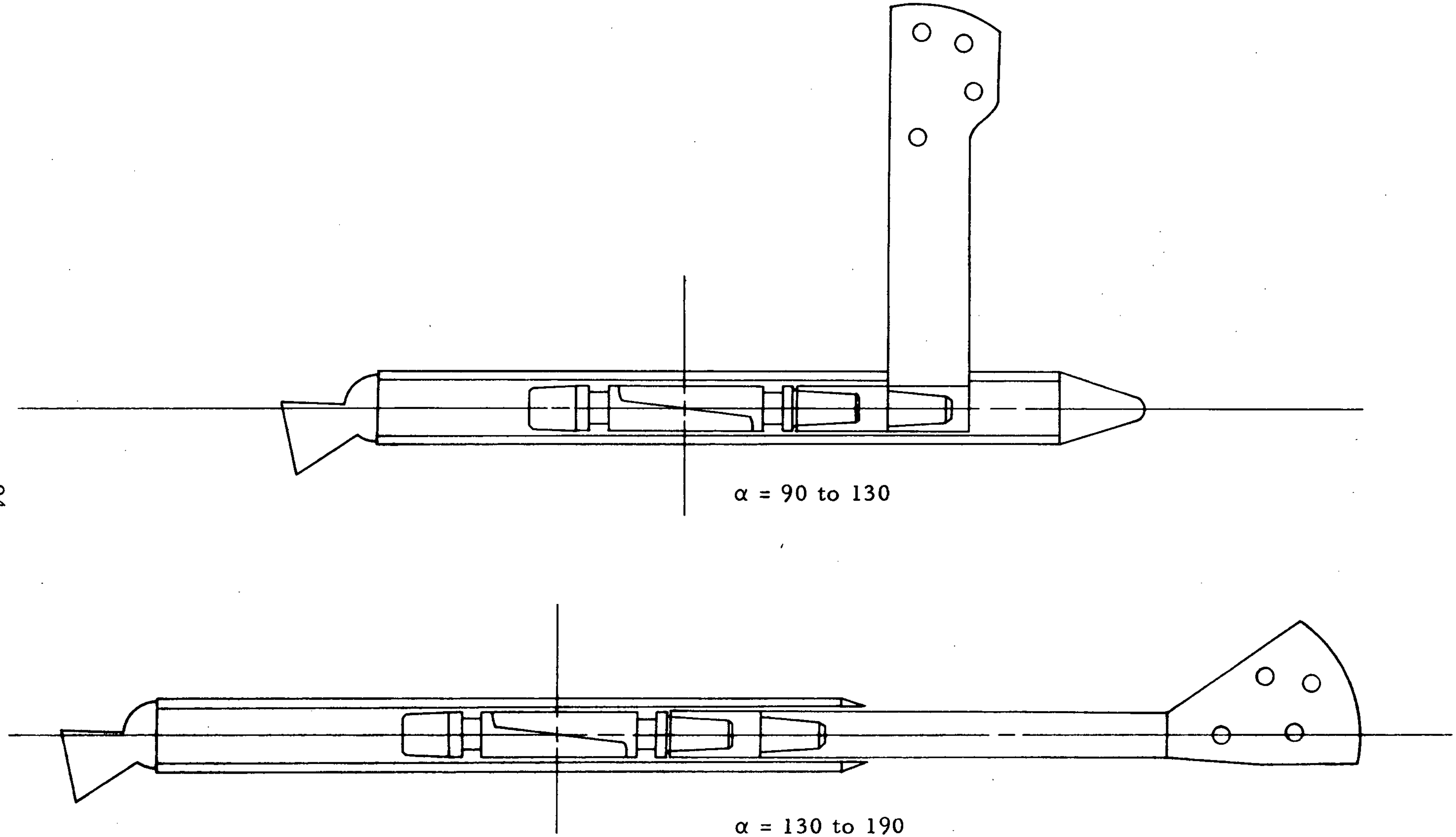


Fig. 19b - Mounting Arrangements for 156-Inch SRM, Angle of Attack 90 to 190 Degrees

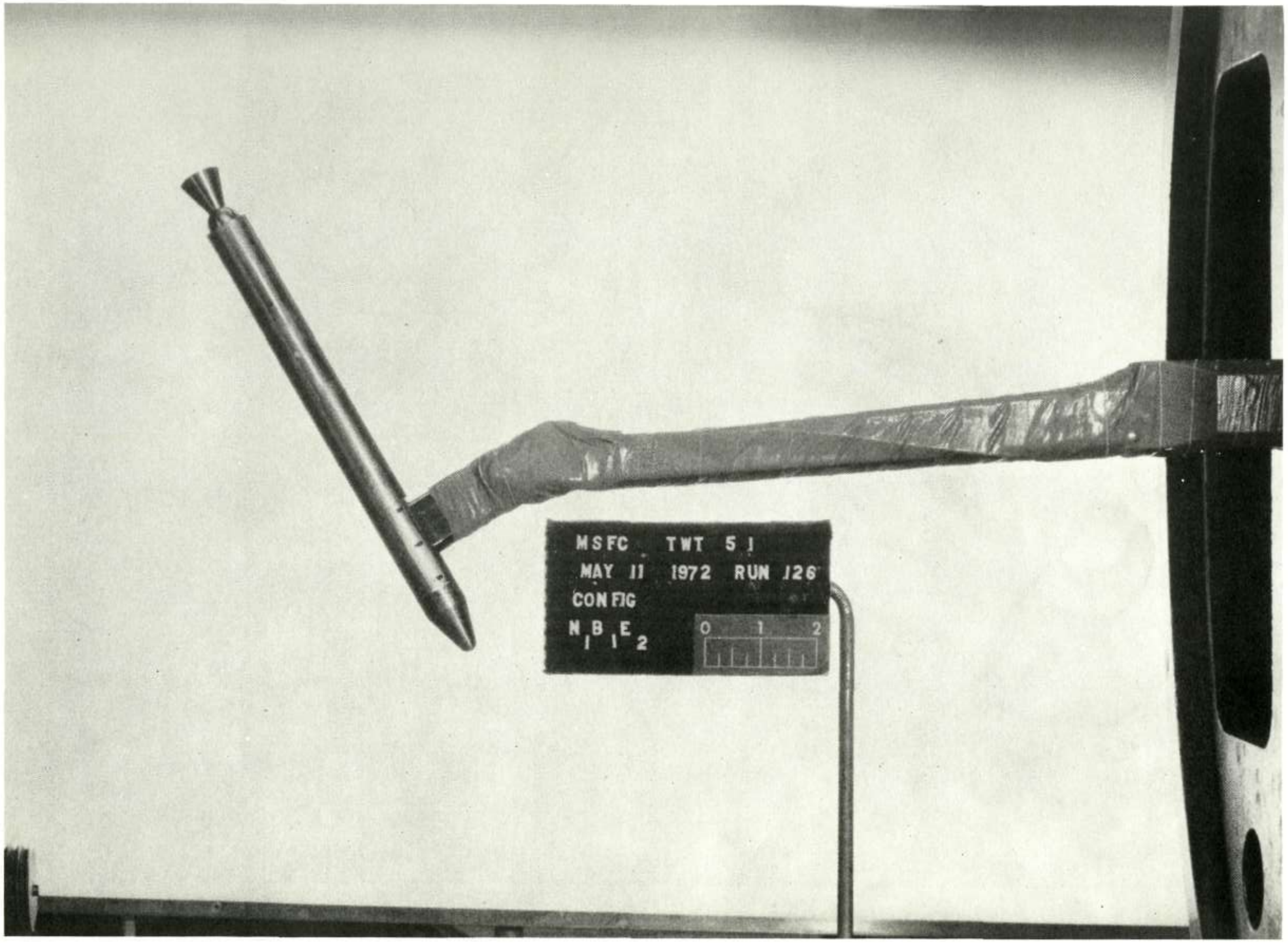


Fig. 20a - Installation Photograph, Solid Rocket Motor (TWT 541)

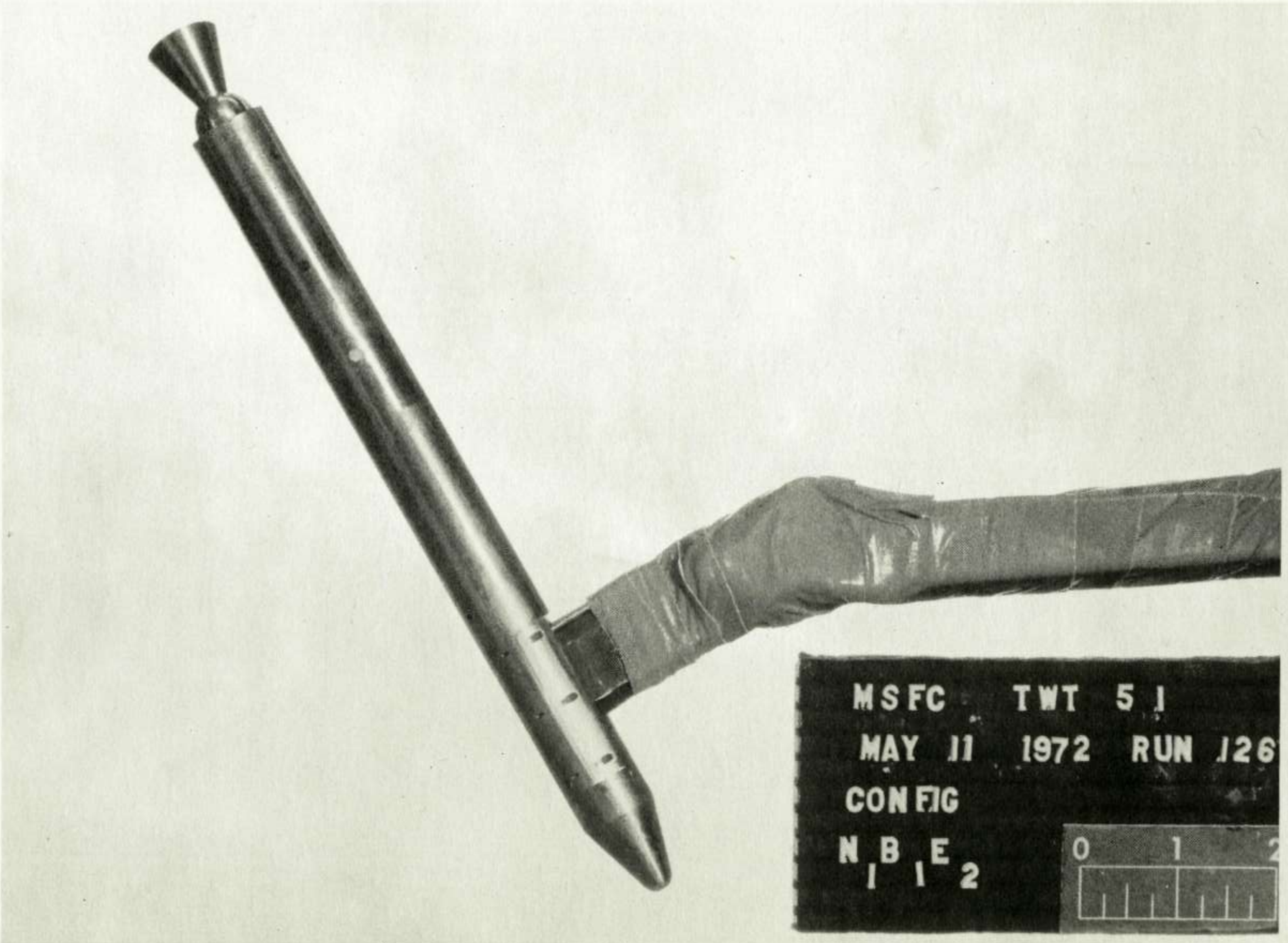


Fig. 20b - Installation Photograph, Solid Rocket Motor (TWT 541)

2.7 STATIC STABILITY AND CONTROL STUDY OF A 0.004-SCALE PARAMETRIC LAUNCH VEHICLE (TWT 544 AND TWT 544X)

2.7.1 Test Purpose

The current configuration of the space shuttle is a parallel burn vehicle with large SRMs arranged around a large liquid hydrogen-oxygen tank. The purpose of these tests was to gain data to optimize the configuration. Parameters varied during the test included HO tank diameter, HO nose shape, SRM radial and longitudinal location, SRM diameter, SRM length, SRM nose shape, orbiter-to-HO tank incidence, and HO tank fins. Orbiter control surface effectiveness while in the launch configuration was also investigated. Tunnel parameters included a Mach number range of 0.6 to 4.96, angles of attack from -10 to 10 degrees, and angles of sideslip from -6 to 6 degrees while at 0 degrees angle of attack. A pretest report was published in May 1972 (Ref. 11).

2.7.2 Test Facility

The test was conducted in the MSFC 14 x 14-Inch Trisonic Wind Tunnel. For a description of this facility see Section 2.1.2.

2.7.3 Model Description

The orbiter is the same configuration as described in 2.2.3. Figures 21, 22 and 23 show the HO tanks and fins and SRMs used to make up the launch configuration. Figure 24 shows the launch configuration. Figure 25 shows installation photographs of the launch configuration. The model nomenclature for this test is:

Symbol	Definition
F	HO tank vertical fin ($S = 1.21\ in^2$)
O1	baseline orbiter (including the abort solid rocket motors)
O2	baseline orbiter less abort solid rocket motors

O3	baseline orbiter without wings
T1	346-in. diam. HO tank with 22-deg nosecone (baseline)
T2	346-in. diam. HO tank with 22-deg nosecone and retro rocket
T3	346-in. diam. HO tank with 17-deg nosecone
T4	346-in. diam. HO tank with 22-deg nosecone and one body diam. length extension
T5	400-in. diam. HO tank with 22-deg nosecone
T6	400-in. diam. HO tank with 22-deg nosecone and retro rocket
T7	same as T1 without structural rings
T8	346-in. diam. HO tank with generalized nosecone
T9	312-in. diam. HO tank with 17-deg nosecone
T10	346-in. diam. HO tank with modified Apollo nosecone
S1	156-in. diam. solid rocket motor with 17-deg nosecone (baseline)
S2	156-in. diam. solid rocket motor with 17-deg nosecone and one body diameter length extension
S3	156-in. diam. solid rocket motor with skewed nose tangent to HO tank
S4	156-in. diam. solid rocket motor with skewed nose turned 180 deg relative to S3 position
S5	178-in. diam. solid rocket motor with 17-deg nosecone
S6	156-in. diam. solid rocket motor with 17-deg nosecone less rocket nozzle

All model parts are made of aluminum.

2.7.4 Data Reduction

Model forces and moments were measured by MSFC balance 232. After corrections were made for sting deflections and weight tares, the forces and moments were reduced to coefficient form by the reference dimensions shown in Table 15.

The data were entered in the Chrysler Corporation System for Analysis and Development of Static Aerothermodynamic Criteria (SADSAC) program, and published as two data reports (Ref. 28 for TWT 544 and Ref. 29 for TWT 544X).

2.7.5 Discussion

An extremely large number of configurations were investigated during these tests. Tables 16 and 17 show the variety of these configurations. The first test (TWT 544) suggested configurations that were later investigated during the second test (TWT 544X).

One hundred thirty-one hours of wind tunnel occupancy time were required for TWT 544 and one hundred sixteen hours were required for TWT 544X.

Table 15

0.004-SCALE SPACE SHUTTLE LAUNCH CONFIGURATION REFERENCE DIMENSIONS

Parameter	Full Scale	Model Scale
Reference Area (S_{ref}) (Wing Theoretical Area)	3420.0 ft^2	7.880 in^2
Reference Length (ℓ_{ref}) (M.A.C.)	507.0 in.	2.028 in.
Reference Span (b_{ref}) (Wing Span)	1115.0 in.	4.460 in.
Balance Location (BMC) (Balance Moment Center) (from base of HO tank)	—	3.293 in.
Moment Reference Point (MRP)	840.0 in.	3.360 in.
Base Area (A_b)		
Q1	318 ft^2	0.732 in^2
S1, S2, S3, S4, S6	133 ft^2	0.306 in^2
S5	173 ft^2	0.398 in^2
T1, T2, T3, T4, T7, T8, T10	653 ft^2	1.504 in^2
T5, T6	872 ft^2	2.010 in^2
T9	530 ft^2	1.221 in^2

Table 16

RUN SCHEDULE FOR TWT 544

DATA SET IDENTIFIER	CONFIGURATION	SCHD. α	SCHD. β	PARAMETERS/VALUES i_{orb}	ϕ_{SRM}	x_{SRM}	δ_e	NO. of RUNS	δ_r	ϕ_{Noz}		0.6	0.9	1.1	1.2	1.3	1.46	1.96	3.48	4.96
	T1φ1S1	A	0	0°	75°	0	0°		0°	0°		✓	✓		✓					✓
				-1.5°								✓	✓	✓	✓	✓	✓	✓	✓	✓
				-3.0°	↓							✓	✓		✓					✓
				0°	90°							✓	✓		✓					✓
				-1.5°								✓	✓		✓		✓	✓	✓	✓
				-3.0°	↓							✓	✓		✓					✓
				0°	135°							✓	✓		✓					✓
				-1.5°								✓	✓		✓		✓	✓	✓	✓
		↓	↓	-3.0°	↓							✓	✓		✓					✓
		0	A	-1.5°	75°							✓	✓		✓			✓	✓	✓
					90°							✓	✓		✓			✓		✓
		↓	↓		135°	↓						✓	✓		✓			✓		✓
		A	0		75°	-.624						✓			✓					
		0	A		75°							✓			✓					
		A	0		90°							✓			✓					
		0	A		90°							✓			✓					
		A	0		135°							✓			✓					
	↓	0	A		135°	↓				↓		✓			✓					
	T1φ1S3	A	0		75°	0				30°					✓					
	↓	0	A	↓	75°	0	↓		↓	30°					✓					

1 7 13 19 25 31 37 43 49 55 61 67 75 76

COEFFICIENTS: → IDPVAR(1) | IDPVAR(2) | NDV

α or β SCHEDULES

α: A = -10° to 10° by Δα = 2°

β: A = -10° to 10° by Δβ = 2°

Table 16 (Continued)

DATA SET IDENTIFIER	CONFIGURATION	SCHD. α	SCHD. β	PARAMETERS/VALUES i_{ORB}	ϕ_{SRM}	X_{SRM}	δ_e	NO. of RUNS	δ_r	ϕ_{NOZ}		0.6	0.9	1.1	1.2	1.3	1.46	1.96	3.48	4.96
	T1 ϕ1 S3	A	0	-1.5°	75°	0	0°		0°	0°					✓			✓	✓	✓
	↓	0	A	↓	↓	↓	↓		↓	↓					✓			✓	✓	✓
	T1 ϕ1 S4	A	0												✓			✓	✓	✓
	↓	0	A							↓					✓			✓	✓	✓
		A	0							30°					✓					
	↓	0	A							30°					✓					
	T1 ϕ1 S2	A	0							0°		✓			✓			✓	✓	✓
	↓	0	A							0°		✓			✓			✓	✓	✓
		0	A							30°		✓			✓					
	↓	0	A							↓		✓			✓					
	T2 ϕ1 S1	A	0												✓					
	↓	0	A							↓					✓					
		A	0							0°					✓			✓	✓	✓
	↓	0	A												✓			✓	✓	✓
	T3 ϕ1 S1	A	0												✓			✓	✓	✓
	↓	0	A							↓					✓			✓	✓	✓
		A	0							30°					✓					
	↓	0	A												✓					
	T4 ϕ1 S1	A	0									✓			✓					
	↓	0	A	↓	↓	↓	↓		↓	↓		✓			✓					

MACH NUMBERS (OR ALTERNATE INDEPENDENT VARIABLE)

1 7 13 19 25 31 37 43 49 55 61 67 75 76

IDPVAR(1) | IDPVAR(2) | NDV

COEFFICIENTS:

α or β SCHEDULES

α: A = -10° to 10° by $\Delta\alpha$ = 2°

β: A = -10° to 10° by $\Delta\beta$ = 2°

Table 16 (Continued)

DATA SET IDENTIFIER	CONFIGURATION	SCHD. α	SCHD. β	PARAMETERS/VALUES i_{ORB}	ϕ_{SRM}	x_{SRM}	δ_e	NO. of RUNS	MACH NUMBERS (OR ALTERNATE INDEPENDENT VARIABLE) δ_r	ϕ_{NOZ}		0.6	0.9	1.1	1.2	1.3	1.46	1.96	3.48	4.96
	T4Φ1S1	A	0	-1.5°	75°	0	0°		0°	0°		✓			✓			✓	✓	✓
		0	A									✓			✓			✓	✓	✓
	T1Φ1S1F	A	0									✓	✓		✓			✓		✓
		0	A									✓	✓		✓			✓		✓
		A	0							30°		✓	✓		✓					
		0	A							30°		✓	✓		✓					
	T5Φ1S1	A	0							0°		✓	✓		✓			✓	✓	✓
		0	A									✓	✓		✓			✓	✓	✓
	T6Φ1S1	A	0									✓	✓		✓			✓	✓	✓
103		0	A									✓	✓		✓			✓	✓	✓
	T1Φ1S5	A	0									✓			✓			✓		✓
		0	A									✓			✓			✓		✓
		A	0		90°							✓			✓			✓		✓
					135°							✓			✓			✓		✓
	T1Φ1S1				75°		-10°					✓	✓		✓					
		0	A				-10°					✓	✓		✓					
		A	0				+10°					✓	✓		✓					
		0	A									✓	✓		✓					
		A	0		90°							✓	✓		✓					
		A	0		90°		-10°					✓	✓		✓					

1 7 13 19 25 31 37 43 49 55 61 67 75 76

COEFFICIENTS: IDPVAR(1) | IDPVAR(2) | NDV

α or β SCHEDULES
α: A = -10° to 10° by $\Delta\alpha$ = 2°
β: A = -10° to 10° by $\Delta\beta$ = 2°

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Table 16 (Continued)

DATA SET IDENTIFIER	CONFIGURATION	SCHD. α	SCHD. β	PARAMETERS/VALUES i_{ORB}	ϕ_{SRM}	x_{SRM}	δ_e	NO. of RUNS	MACH NUMBERS (OR ALTERNATE INDEPENDENT VARIABLE) δ_r	ϕ_{NOZ}		0.6	0.9	1.1	1.2	1.3	1.46	1.96	3.48	4.96
	T1φ1S1	A	0	-1.5°	135°	0	-10°		0°	0°		✓	✓		✓					
	↓	↓	↓	↓	135°	↓	+10°		↓	↓		✓	✓		✓					
	T1φ2S1	↓	↓	↓	75°	↓	+10°		↓	↓					✓			✓	✓	✓
	↓	↓	↓	↓	↓	↓	-10°		↓	↓					✓			✓	✓	✓
	↓	↓	↓	↓	↓	↓	-30°		↓	↓					✓			✓	✓	✓
	T1φ1S1	↓	↓	↓	↓	↓	0°		30°	↓		✓	✓		✓			✓		✓
	↓	0	A	↓	↓	↓	↓		30°	↓		✓	✓		✓			✓		✓
	T1φ3S1	A	0	↓	↓	↓	↓		0°	↓			✓	✓	✓	✓				
	T7	↓	↓	—	—	—	—		—	—		✓	✓		✓					
	T1S1	↓	↓	↓	75°	0	—		—	0°		✓	✓		✓			✓	✓	✓
	↓	0	A	↓	75°	0	—		—	0°		✓			✓			✓		✓
	T1φ1	A	0	-1.5°	—	—	0°		0°	—		✓	✓		✓			✓	✓	✓
	↓	0	A	-1.5°	↓	↓	0°		0°	↓		✓			✓			✓		✓
	T5	A	0	—	↓	↓	—		—	↓		✓	✓		✓			✓	✓	✓
	T5S1	A	0	↓	75°	0	↓		↓	0°		✓	✓		✓			✓	✓	✓
	↓	0	A	↓	75°	0	↓		↓	0°		✓			✓			✓		✓
	T5φ1	A	0	-1.5°	—	—	0°		0°	—		✓	✓		✓			✓	✓	✓
	↓	0	A	↓	—	—	↓		↓	—		✓			✓			✓		✓
	T1φ2S1	A	0	↓	75°	0	↓		↓	0°					✓			✓	✓	✓
	T1	A	0	—	—	—	—		—	—		✓	✓		✓			✓	✓	✓

1 7 13 19 25 31 37 43 49 55 61 67 75 76

IDPVAR(1) | IDPVAR(2) | NDV

COEFFICIENTS:

α or β SCHEDULES

α: A = -10° to 10° by Δα = 2°

β: A = -10° to 10° by Δβ = 2°

Table 16 (Concluded)

DATA SET IDENTIFIER	CONFIGURATION	SCHD. α	SCHD. β	PARAMETERS/VALUES i_{ORB}	ϕ_{SRB}	x_{SRB}	δ_e	NO. of RUNS	MACH NUMBERS (OR ALTERNATE INDEPENDENT VARIABLE) δ_r	ϕ_{NOZ}		0.6	0.9	1.1	1.2	1.3	1.46	1.96	3.48	4.96
	T5φ1S1	A	0	-1.5°	75°	0	0°		0°	30°		✓			✓					
	↓	0	A	↓	↓	0	↓		↓	30°		✓			✓			✓		✓
	T1φ1S1	A	0			.885				0°		✓			✓			✓		✓
	↓	0	A		↓	↓				↓		✓			✓			✓		✓
		A	0		90°							✓			✓			✓		✓
		0	A		90°							✓			✓			✓		✓
		A	0		135°							✓			✓			✓		✓
	↓	0	A	↓	135°	↓	↓		↓	↓		✓			✓			✓		✓

1 7 13 19 25 31 37 43 49 55 61 67 75 76

COEFFICIENTS: → IDPVAR(1) | IDPVAR(2) | NDV

α or β SCHEDULES

α: A = -10° to 10° by Δα = 2°

β: A = -10° to 10° by Δβ = 2°

Table 17

RUN SCHEDULE FOR TWT 544X

DATA SET IDENTIFIER	CONFIGURATION	SCHD. α	SCHD. β	PARAMETERS/VALUES δ_e	δ_r	i_{ORB}	Y_{SRM}	NO. of RUNS	MACH NUMBERS (OR ALTERNATE INDEPENDENT VARIABLE) 0.6	0.8	0.9	1.0	1.1	1.2	1.46	1.96	3.4	4.96		
	T3φ1S1	A	0	0°	0°	0°	.023		✓	✓	✓	✓	✓	✓						
	↓	0	A						✓	✓	✓	✓	✓	✓						
	T3φ2S1	A	0											✓	✓	✓	✓	✓		
		0	A		↓									✓	✓	✓	✓	✓		
		A	0		30°									✓	✓	✓	✓	✓		
	↓	0	A											✓	✓	✓	✓	✓		
	T3φ1S1	A	0						✓	✓	✓	✓	✓	✓						
		0	A	↓	↓				✓	✓	✓	✓	✓	✓						
		A	0	10°	0°				✓	✓	✓	✓	✓	✓						
	↓	0	A						✓	✓	✓	✓	✓	✓						
	T3φ2S1	A	0											✓	✓	✓	✓	✓		
		0	A	↓										✓	✓	✓	✓	✓		
		A	0	-10°										✓	✓	✓	✓	✓		
	↓	0	A											✓	✓	✓	✓	✓		
	T3φ1S1	A	0						✓	✓	✓	✓	✓	✓						
		0	A	↓			↓		✓	✓	✓	✓	✓	✓						
		A	0	0°			.073		✓	✓	✓			✓						
		0	A				.073		✓	✓	✓			✓						
		A	0				.123		✓	✓	✓			✓						
	↓	0	A	↓	↓	↓	.123		✓	✓	✓			✓						

1 7 13 19 25 31 37 43 49 55 61 67 75 76

COEFFICIENTS: → IDPVAR(1) | IDPVAR(2) | NDV

α or β SCHEDULES

α: A = -10° to 10° by $\Delta\alpha$ = 2°

β: A = -10° to 10° by $\Delta\beta$ = 2°

Table 17 (Continued)

DATA SET IDENTIFIER	CONFIGURATION	SCHD. α	SCHD. β	PARAMETERS/VALUES δ_e	δ_r	i_{ORB}	Y_{SRM}	NO. of RUNS	MACH NUMBERS (OR ALTERNATE INDEPENDENT VARIABLE) 0.6	0.8	0.9	1.0	1.1	1.2	1.46	1.96	3.48	4.96		
	T3φ1S1	A	0	0°	0°	0°	.223		✓	✓	✓			✓						
	↓	0	A				.223		✓	✓	✓			✓						
	T3φ2S1	A	0				.073									✓		✓		
		0	A				.073									✓		✓		
		A	0				.123									✓		✓		
		0	A				.123									✓		✓		
		A	0				.223									✓		✓		
	↓	0	A				.223									✓		✓		
	T3φ2S6	A	0				.023								✓	✓				
	↓	0	A												✓	✓				
	T3φ1S6	A	0								✓			✓						
	↓	0	A								✓			✓						
	T8φ1S1	A	0			-1.5°			✓	✓	✓	✓	✓	✓						
	↓	0	A						✓	✓	✓	✓	✓	✓						
	T8φ2S1	A	0											✓	✓	✓	✓	✓		
	↓	0	A											✓	✓	✓	✓	✓		
	T10φ2S1	A	0											✓	✓	✓	✓	✓		
	↓	0	A											✓	✓	✓	✓	✓		
	T10φ1S1	A	0						✓	✓	✓	✓	✓	✓						
	↓	0	A	↓	↓	↓	↓		✓	✓	✓	✓	✓	✓						

1 7 13 19 25 31 37 43 49 55 61 67 75 76

COEFFICIENTS: → IDPVAR(1) | IDPVAR(2) | NDV

α or β SCHEDULES

α: A = -10° to 10° by Δα = 2°

β: A = -10° to 10° by Δβ = 2°

Table 17 (Continued)

DATA SET IDENTIFIER	CONFIGURATION	SCHD. α	SCHD. β	PARAMETERS/VALUES δe	δr	i_{ORB}	Y_{SRM}	NO. of RUNS	MACH NUMBERS (OR ALTERNATE INDEPENDENT VARIABLE) 0.6	0.8	0.9	1.0	1.1	1.2	1.46	1.96	3.48	4.96		
	T9φ1S1	A	0	0°	0°	-1.5°	.023		✓	✓	✓	✓	✓	✓						
		0	A						✓	✓	✓	✓	✓	✓						
	T9φ2S1	A	0											✓	✓	✓	✓	✓		
		0	A											✓	✓	✓	✓	✓		
		A	0			0°								✓	✓	✓	✓	✓		
		0	A											✓	✓	✓	✓	✓		
	T9φ1S1	A	0						✓	✓	✓	✓	✓	✓						
		0	A						✓	✓	✓	✓	✓	✓						
		A	0		30°				✓		✓			✓						
		0	A						✓		✓			✓						
	T9φ2S1	A	0												✓	✓	✓	✓		
		0	A												✓	✓	✓	✓		
		A	0	10°	0°										✓	✓	✓	✓		
		0	A												✓	✓	✓	✓		
	T9φ1S1	A	0						✓		✓			✓						
		0	A						✓		✓			✓						
		A	0	-10°					✓		✓			✓						
		0	A						✓		✓			✓						
	T9φ2S1	A	0												✓	✓	✓	✓		
		0	A												✓	✓	✓	✓		

1 7 13 19 25 31 37 43 49 55 61 67 75 76

COEFFICIENTS: IDPVAR(1) IDPVAR(2) NDV

α or β SCHEDULES

α: A = -10° to 10° by Δα = 2°

β: A = -10° to 10° by Δβ = 2°

Table 17 (Concluded)

DATA SET IDENTIFIER	CONFIGURATION	SCHD. α	SCHD. β	PARAMETERS/VALUES δ_e	δ_r	i_{ORB}	Y_{SRM}	NO. of RUNS	MACH NUMBERS (OR ALTERNATE INDEPENDENT VARIABLE) 0.6	0.8	0.9	1.0	1.1	1.2	1.46	1.96	3.48	4.96		
	T1ϕ2 S1	A	0	0°	0°	-1.5°	.023									✓		✓		
	↓	0	A	0°	0°	-1.5°	.023									✓		✓		

1 7 13 19 25 31 37 43 49 55 61 67 75 76

COEFFICIENTS: → IDPVAR(1) | IDPVAR(2) | NDV

α or β SCHEDULES

α: A = -10° to 10° by Δα = 2°

β: A = -10° to 10° by Δβ = 2°

Note: All dimensions in inches (model scale)

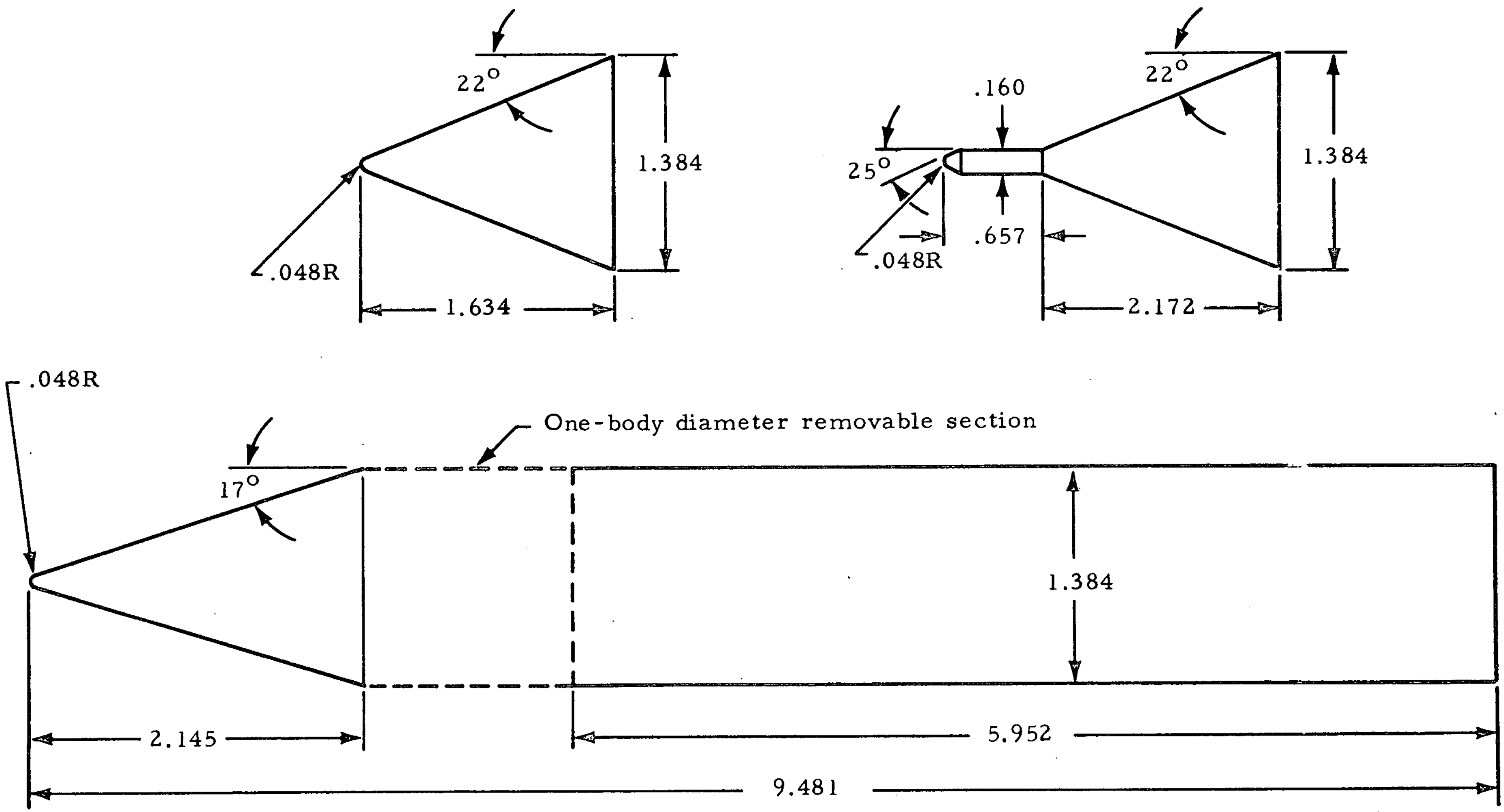


Fig. 21a - 346-Inch HO Tank with Three Alternate Noses and One-Body Diameter Extension

Note: All dimensions in inches (model scale)

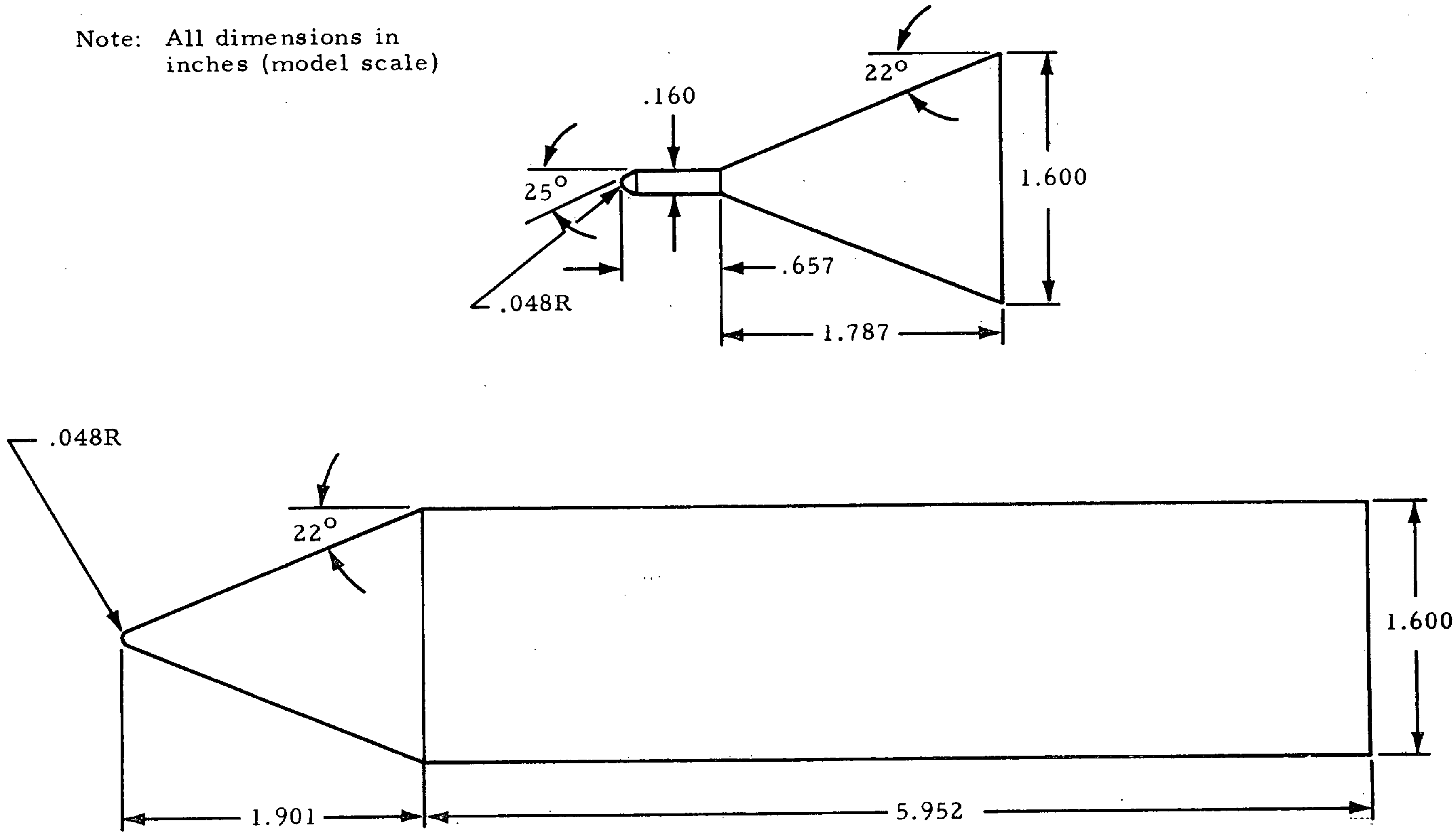


Fig. 21b - 400-Inch HO Tank with Two Alternate Noses

Note: All dimensions in inches

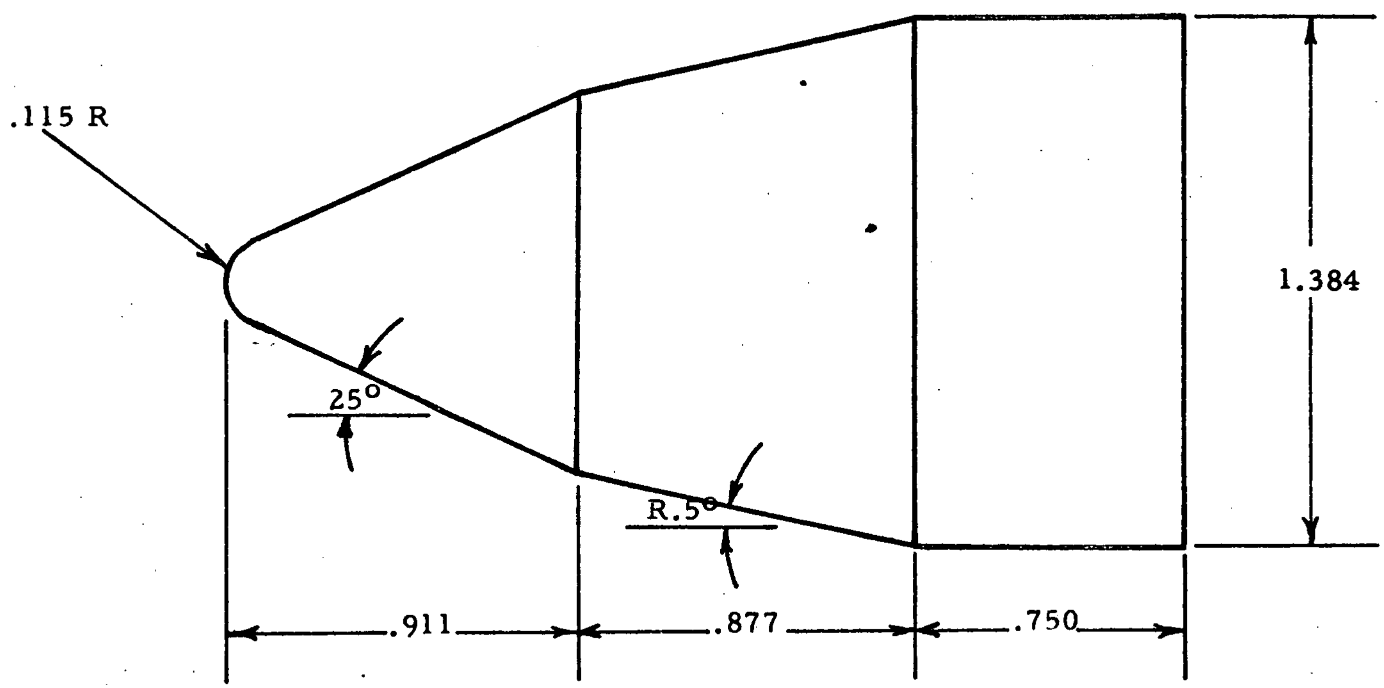


Fig. 21c - T8 346 Inch HO Tank Nose Cone

NOTE: Dimensions are in Inches

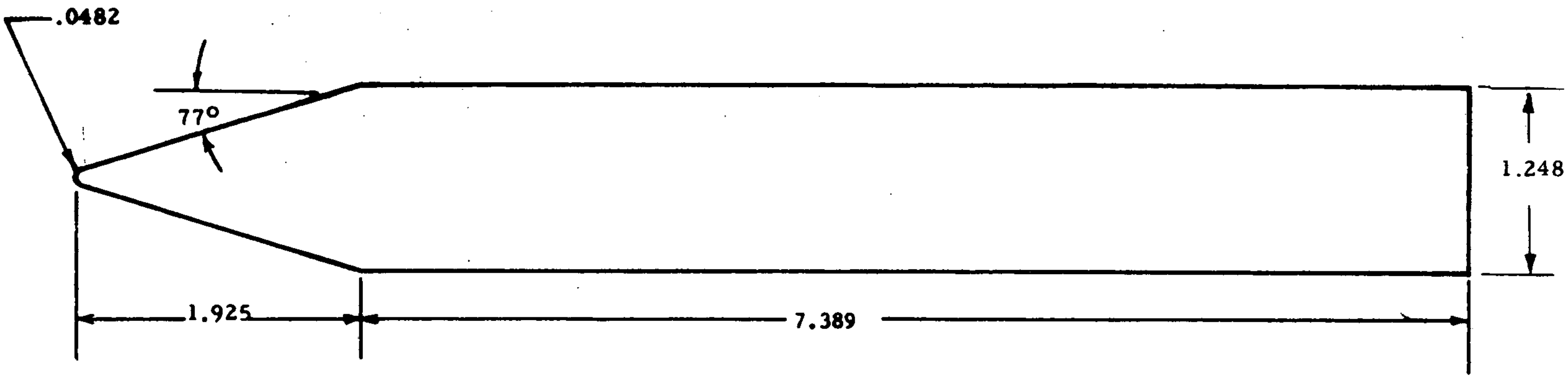
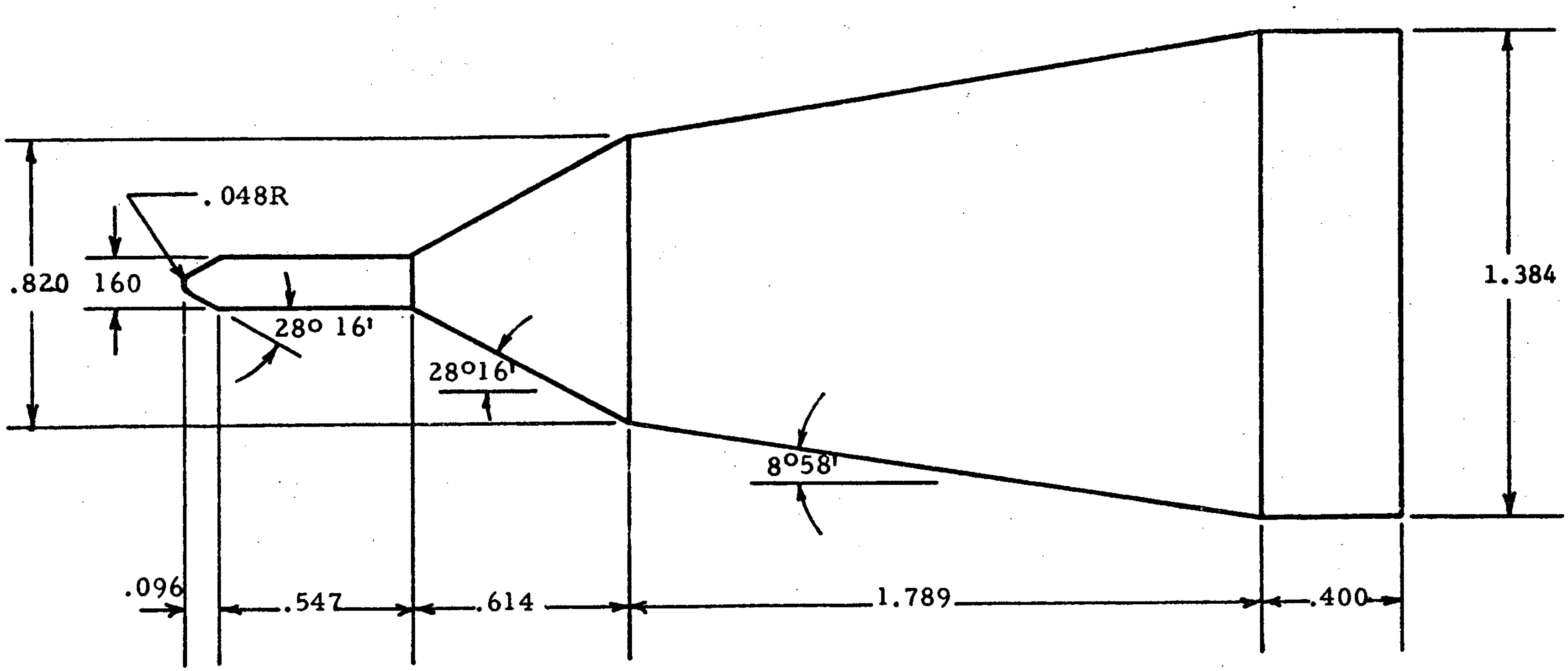


Fig. 21d - T9 312-Inch Diameter HO Tank



All dimensions in inches

Fig. 21e - T10 346 Inch HO Tank Nose Cone

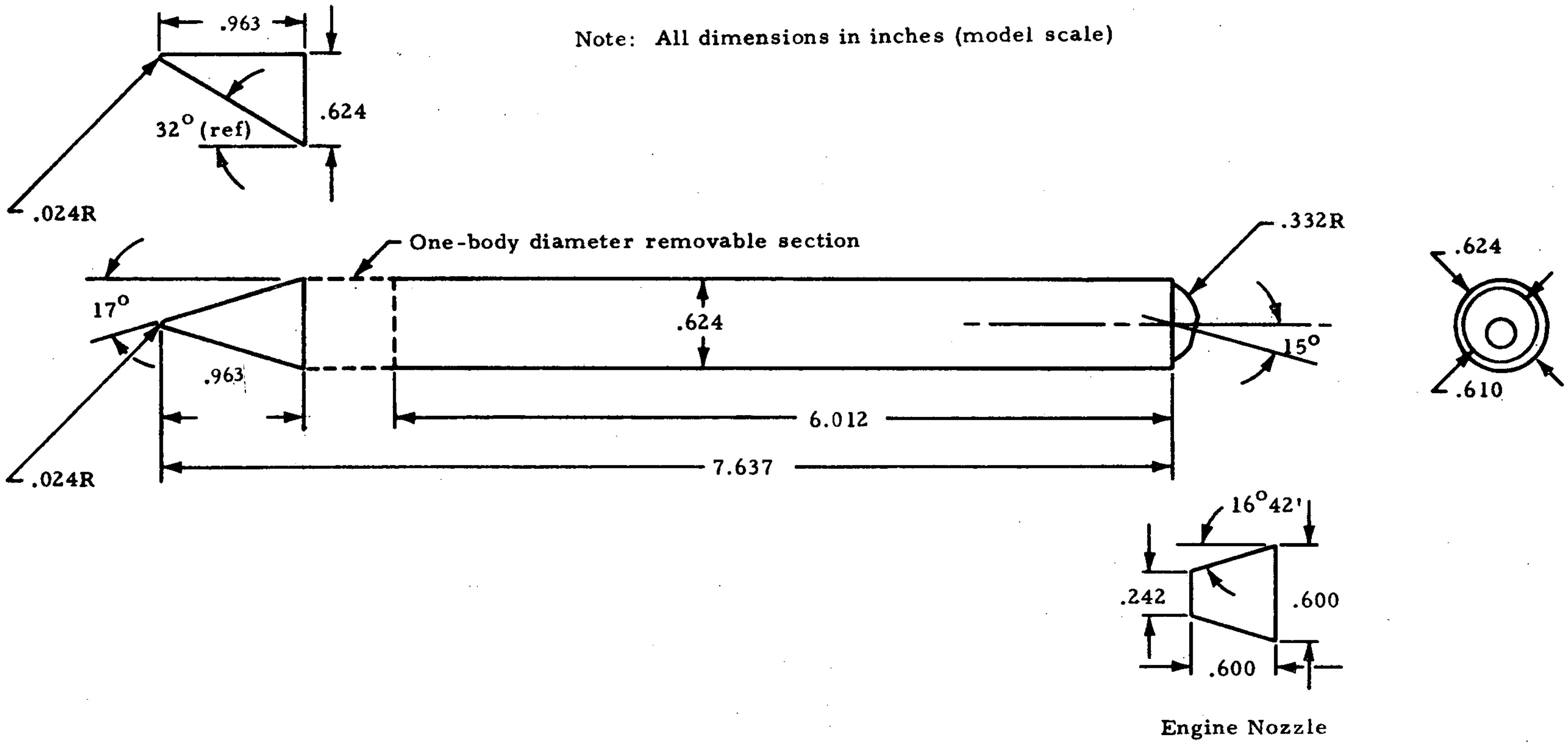


Fig. 22a - 156-Inch Solid Rocket Motor with Standard and Skewed Noses and One-Body Diameter Extension

Note: All dimensions in inches (model scale)

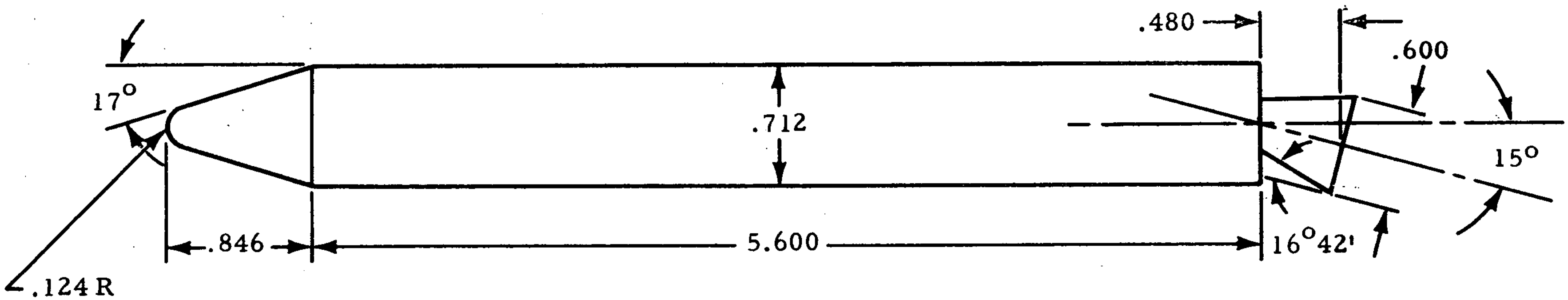


Fig. 22b - 178-Inch Solid Rocket Motor

Note: All dimensions in inches (model scale)

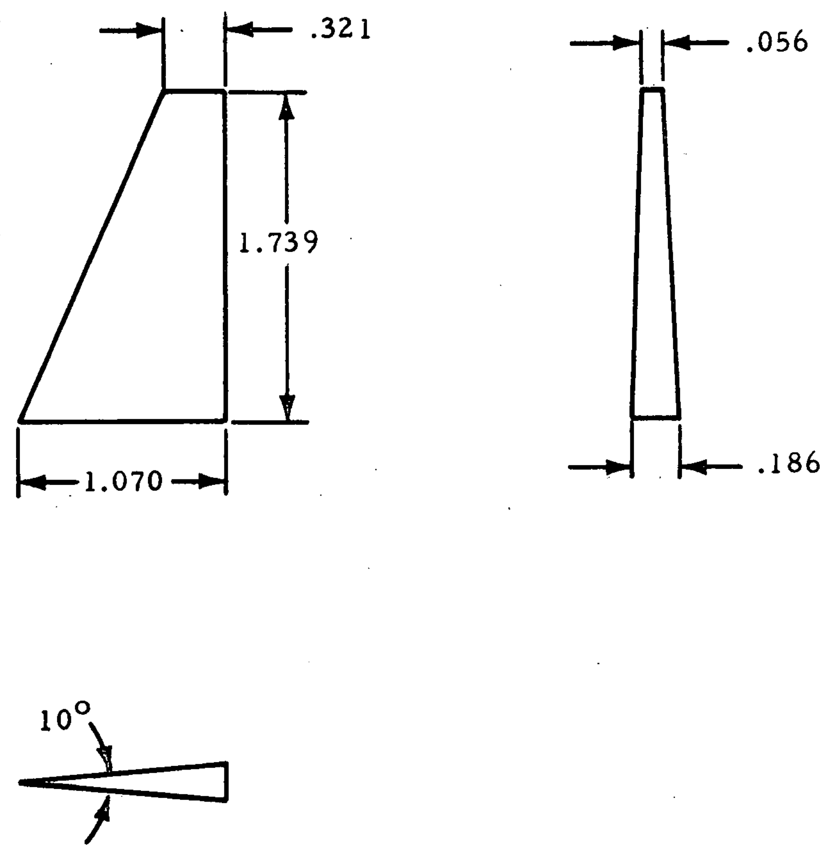


Fig. 23 - HO Tank Ventral Fin

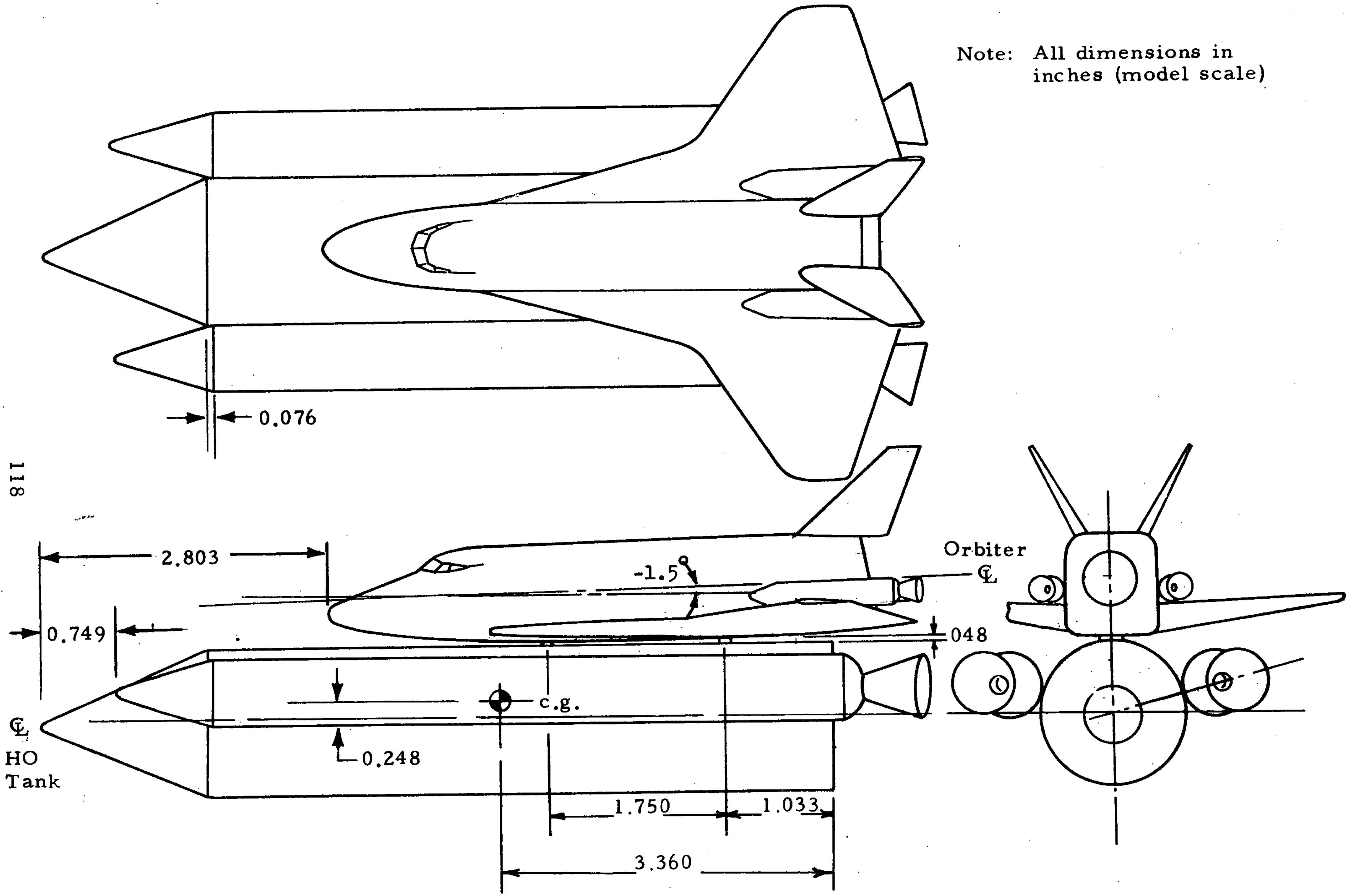


Fig. 24 - Baseline Double Delta Wing Orbiter Launch Vehicle

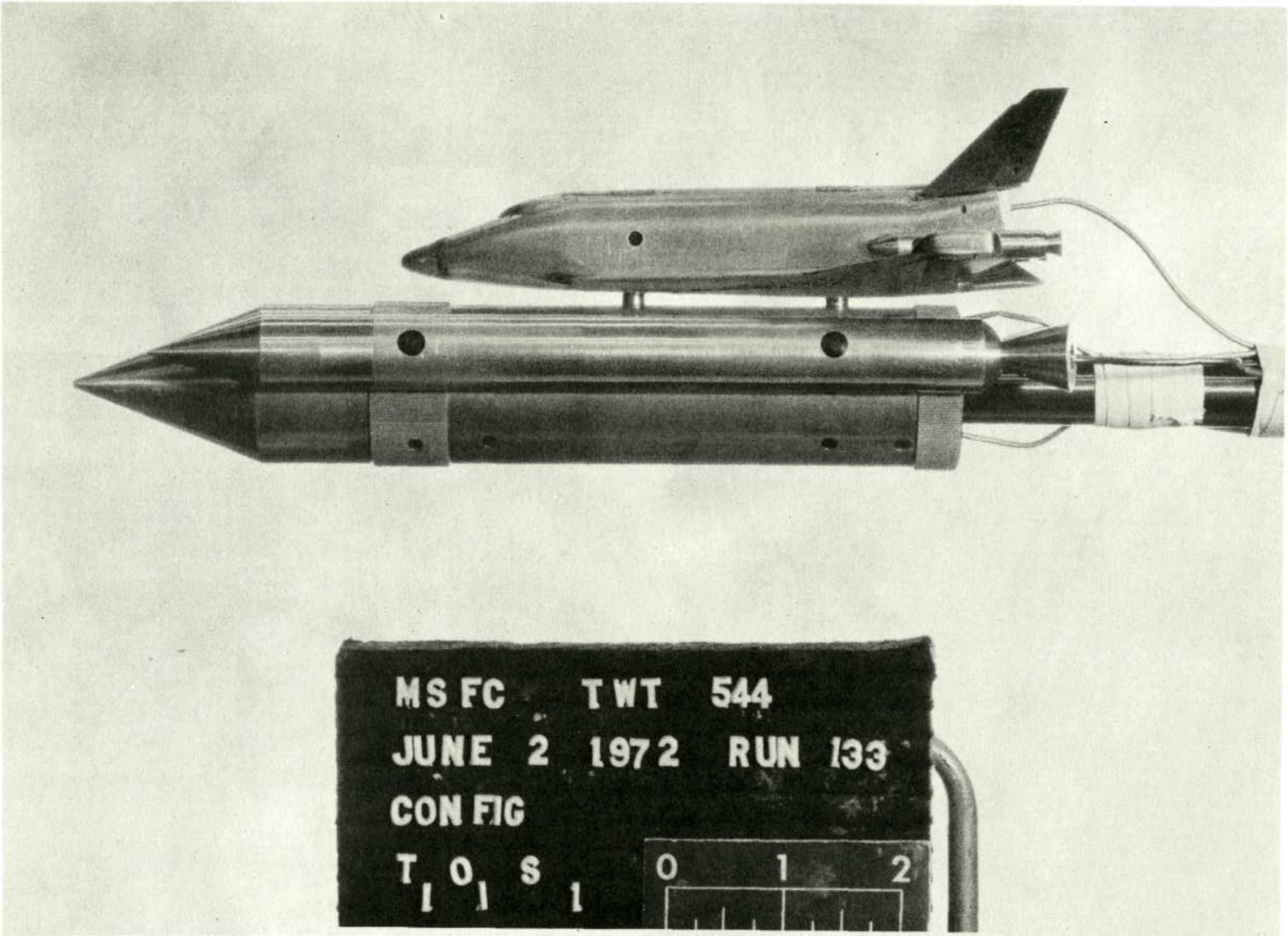


Fig. 25a - Installation Photograph, Double Delta Wing Orbiter Launch Vehicle (TWT 544)

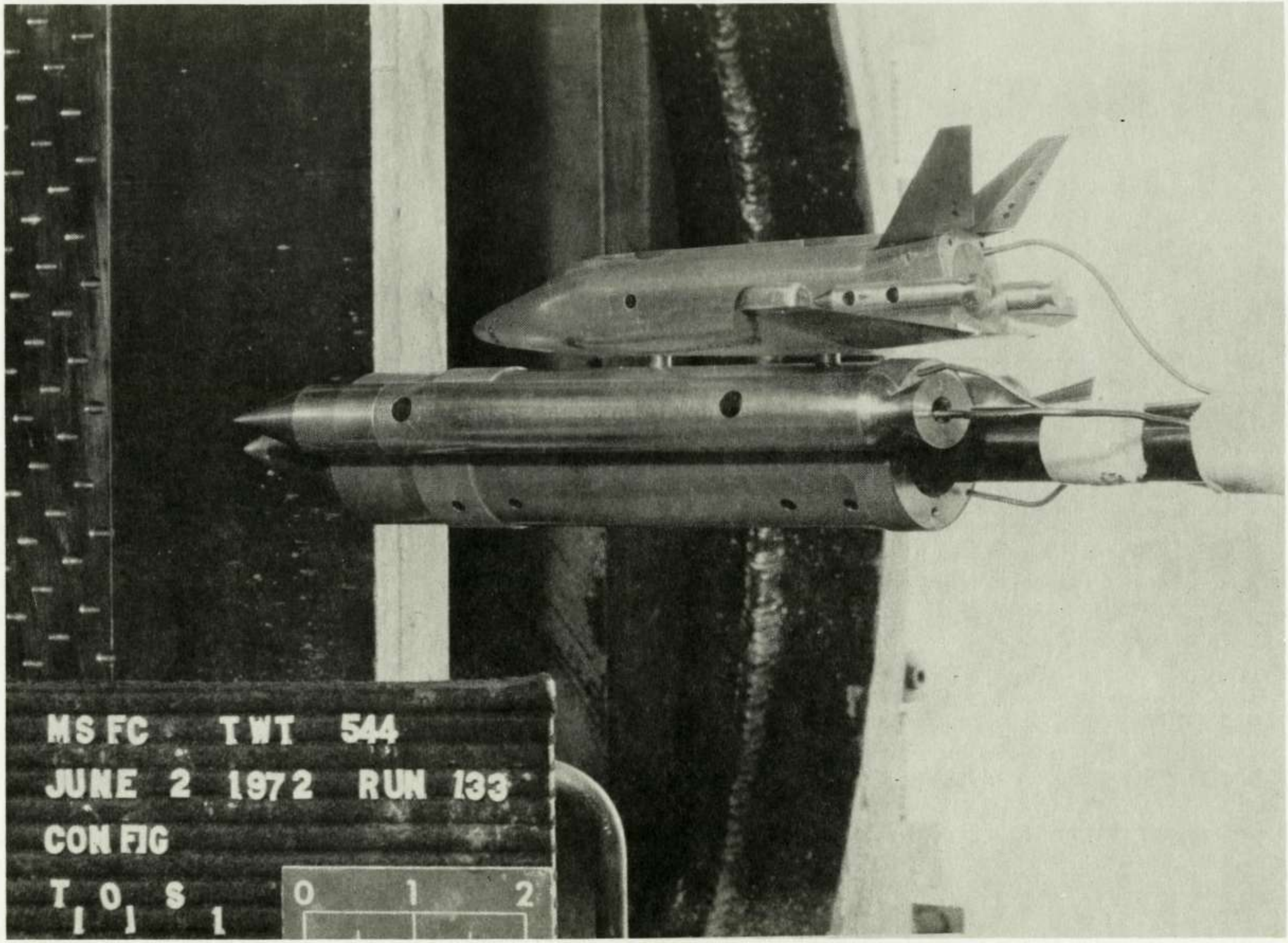


Fig. 25b - Installation Photograph, Double Delta Wing Orbiter Launch Vehicle (TWT 544)

2.8 ORBITER PRESSURE DISTRIBUTION OF A 0.004-SCALE ORBITER WHILE MOUNTED IN THE LAUNCH CONFIGURATION (TWT 550)

2.8.1 Test Purpose

Mounting of the orbiter in proximity to the external HO tank and the solid rocket motors imposes interference loads upon the orbiter. To determine the localized loads on the panels of the orbiter wing, static pressure taps were located on one wing panel on both upper and lower surfaces and down the lower surface centerline of the body. The orbiter was then tested in the launch configuration to determine local panel loads.

The test Mach number range was from 0.6 to 4.96, the angle of attack range was -8 to 8 degrees and the angle of sideslip was -6 to 6 degrees. A pretest report for this test was published in July 1972 (Ref. 30).

2.8.2 Test Facility

The test was conducted in the MSFC 14 x 14-Inch Trisonic Wind Tunnel This facility is described in Section 2.1.2.

2.8.3 Model Description

The HO tank and the solid rocket motors for the launch configuration are the same as those described in Section 2.7.3. The orbiter is the same configuration as the one described in Section 2.2.3 except that it lacks the wingtip pods of the attitude control propulsion system. The orbiter is physically different in that the wing is made of aluminum and has static pressure taps on the upper and lower surface of the left-hand panel. A row of taps is also located on the lower surface longitudinal centerline. Table 18 and Fig. 26 show the location of these static pressure taps. The body of the orbiter is made of Stycast and the vertical fins are made of aluminum.

Figure 27 shows the model installed in the tunnel. The model nomenclature for the test is:

Symbol	Definition
O1	baseline orbiter (including the abort solid rocket motors)
O2	baseline orbiter less abort solid rocket motors
T1	346-in. diam. HO tank with 22-deg nosecone
T3	346-in. diam. HO tank with 17-deg nosecone
S1	156-in. diam. solid rocket motor with 17-deg nosecone (baseline)

2.8.4 Data Reduction

Static pressure data were recorded by the use of Scanivalves containing 5 psid transducers for Mach numbers of 0.6 to 1.96 and 50 psid transducers for Mach numbers of 2.74 and 4.96. The data were referenced to tunnel static pressure and reduced as nondimensional pressure coefficients.

The data were entered into the Chrysler SADSAC program and will soon be published as a data report (Ref. 31).

2.8.5 Discussion

This test was a follow-on of an earlier orbiter pressure test of the same configuration. Orbiter-to-tank incidence angle, SRM radial location, and a new HO tank nose were evaluated during this test. Table 19 shows a listing of all configurations tested.

Sixty-nine hours of wind tunnel occupancy time were required to complete the study.

Table 18

ORBITER SURFACE PRESSURE TAP LOCATIONS

Tap Number	X/L_{local}	$Y/0.5\ b_{ref}$	L_{local} (in.)	$0.5\ b_{ref}$ (in.)
1	.230	.844	.944	2.23
2	.764	—	—	—
3	.243	.564	1.623	—
4	.497	—	—	—
5	.750	—	—	—
6	.134	.294	3.225	—
7	.292	—	—	—
8	.466	—	—	—
9	.647	—	—	—
10	.823	—	—	—
11	.044	0	5.275	—
12	.091	—	—	—
13	.148	—	—	—
14	.225	—	—	—
15	.304	—	—	—
16	.455	—	—	—
17	.944	—	—	—
18	.135	.286	3.225	—
19	.293	—	—	—
20	.469	—	—	—
21	.646	—	—	—
22	.823	—	—	—
23	.223	.555	1.623	—
24	.498	—	—	—
25	.749	—	—	—
26	.246	.846	.944	—
27	.768	—	—	—

Table 19

RUN SCHEDULE FOR TWT 550

DATA SET IDENTIFIER	CONFIGURATION	SCHD. α	SCHD. β	PARAMETERS/VALUES i_{ORB}	ϕ_{SRM}			NO. of RUNS	MACH NUMBERS (OR ALTERNATE INDEPENDENT VARIABLE) 0.6	0.9	1.0	1.1	1.2	1.46	1.96	4.96				
	T3ϕ1S1	A	0	-1.5°	75°				✓	✓	✓	✓	✓							
		0	A						✓	✓	✓	✓	✓							
	T3ϕ2S1	A	0										✓	✓	✓					
		0	A										✓	✓	✓					
		B	0	0.0°									✓	✓	✓					
		0	B	0.0°									✓	✓	✓					
		B	0	-1.5°												✓				
		0	B	-1.5°												✓				
		C	0	0.0°												✓				
		0	C													✓				
	T3ϕ1S1	A	0						✓	✓	✓	✓	✓							
		0	A						✓	✓	✓	✓	✓							
		A	0		90°				✓	✓	✓	✓	✓							
		0	A						✓	✓	✓	✓	✓							
	T3ϕ2S1	A	0										✓	✓	✓					
		0	A										✓	✓	✓					
		A	0	-1.5°									✓	✓	✓					
		0	A										✓	✓	✓					
		B	0													✓				
		0	B													✓				

1 7 13 19 25 31 37 43 49 55 61 67 75 76

IDPVAR(1) | IDPVAR(2) | NDV

COEFFICIENTS:

α or β SCHEDULES

α: A = −8° to 8° by Δα = 2°; B = −6°, 0°, 2°, 6°; C = −8°, −6°, −4°, 0°, 2°, 4°, 6°, 8°

β: A = −6° to 6° by Δβ = 2°; B = −6°, 0°, 2°, 6°; C = −6°, −4°, 0°, 2°, 4°, 6°

Table 19 (Concluded)

DATA SET IDENTIFIER	CONFIGURATION	SCHD. α	SCHD. β	PARAMETERS/VALUES i_{DRB}	ϕ_{SRM}			NO. of RUNS	0.6	0.9	1.0	1.1	1.2	1.46	1.96	4.96				
	T3φ2S1	C	O	0.0°	90°											✓				
	↓	O	C	0.0°												✓				
	T3φ1S1	A	O	-1.5°					✓	✓	✓	✓	✓							
		O	A		↓				✓	✓	✓	✓	✓							
		A	O		135°				✓	✓	✓	✓	✓							
		O	A	↓					✓	✓	✓	✓	✓							
		A	O	0.0°					✓	✓	✓	✓	✓							
	↓	O	A						✓	✓	✓	✓	✓							
	T3φ2S1	A	O										✓	✓	✓					
		O	A	↓									✓	✓	✓					
		A	O	-1.5°									✓	✓	✓					
	↓	O	A		↓								✓	✓	✓					
	T1φ1S1	A	O		75°								✓							
	↓	O	A	↓	75°								✓							

1 7 13 19 25 31 37 43 49 55 61 67 75 76

COEFFICIENTS: → IDPVAR(1) | IDPVAR(2) | NDV

α or β SCHEDULES

α: A = -8° to 8° by Δα = 2°; B = -6°, 0°, 2°, 6°; C = -8°, -6°, -4°, 0°, 2°, 4°, 6°, 8°

β: A = -6° to 6° by Δα = 2°; B = -6°, 0°, 2°, 6°; C = -6°, -4°, 0°, 2°, 4°, 6°, 8°

Numbers in parenthesis are on the lower surface

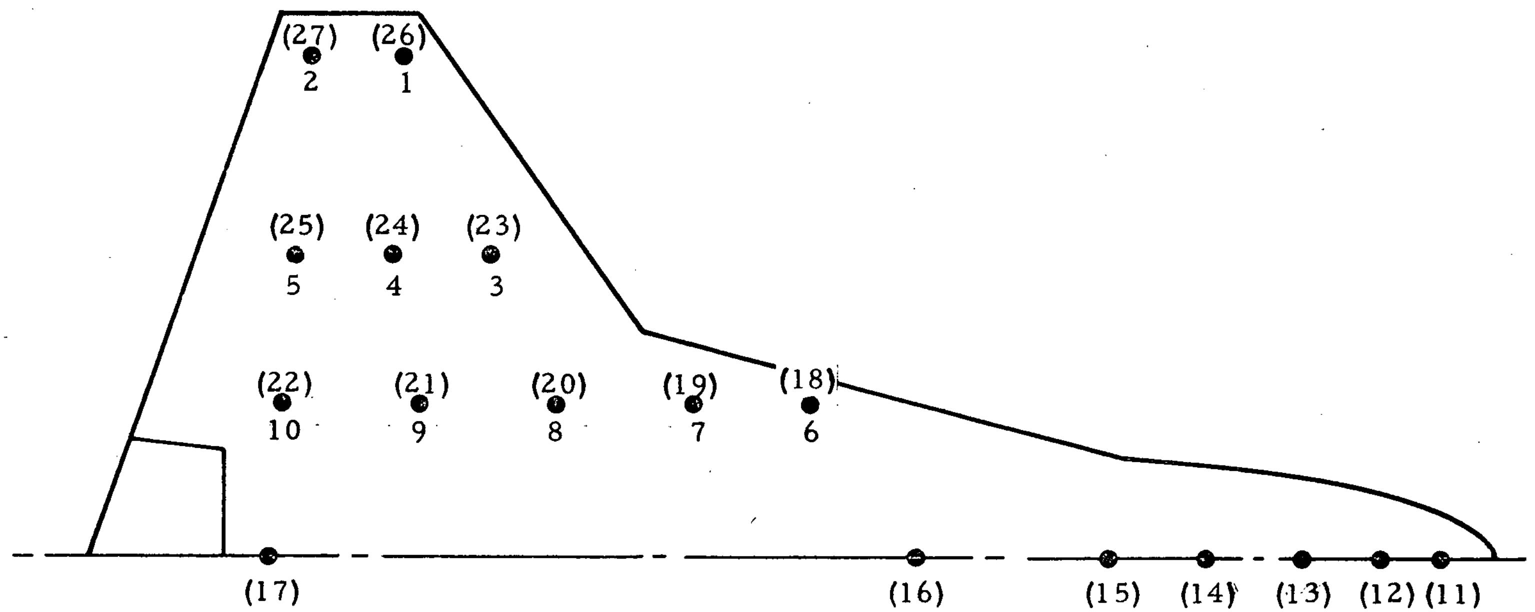


Fig. 26 - Static Pressure Tap Positions for Double Delta Orbiter

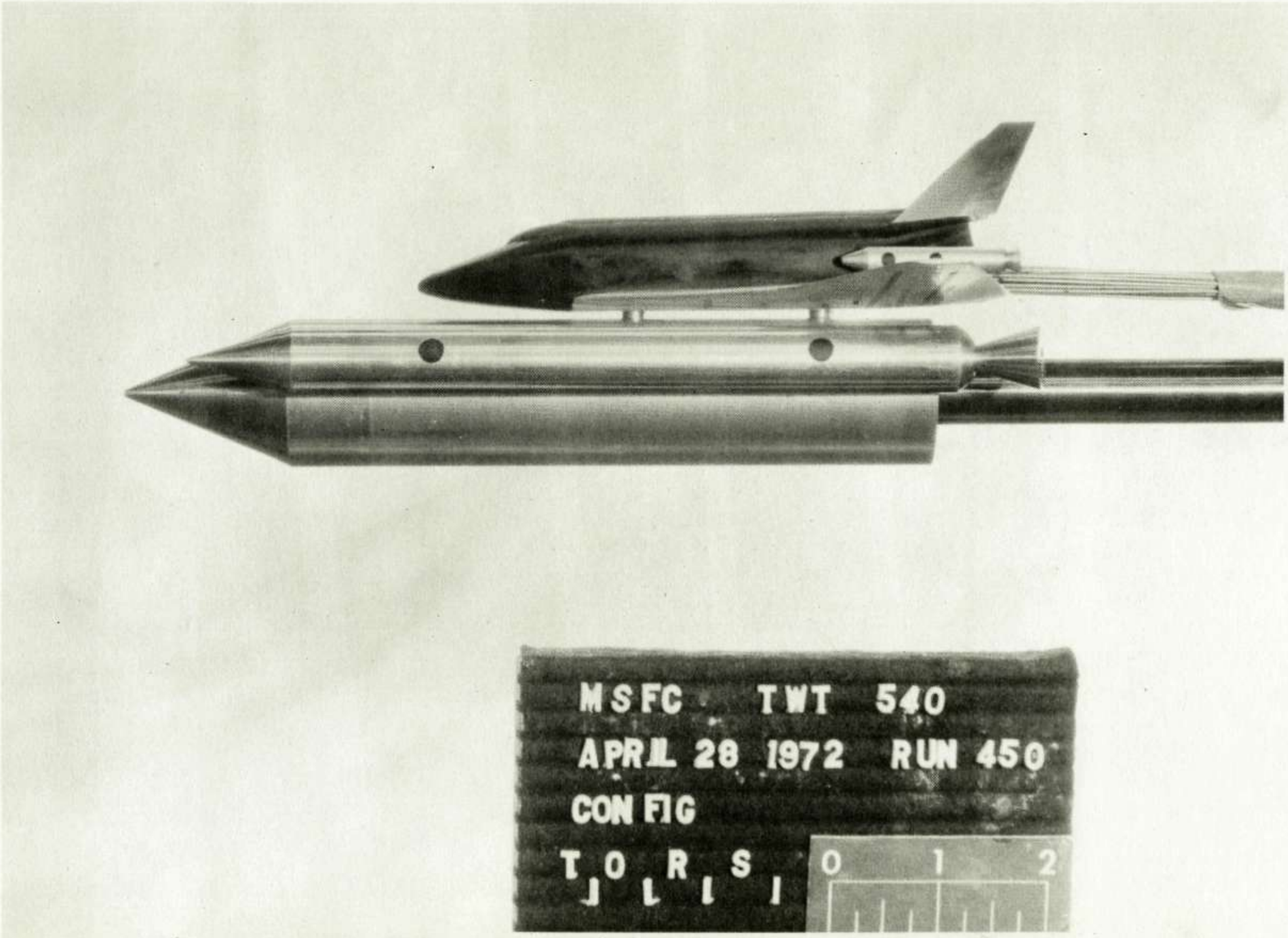


Fig. 27a - Installation Photograph, Orbiter Pressure Test (TWT 550)

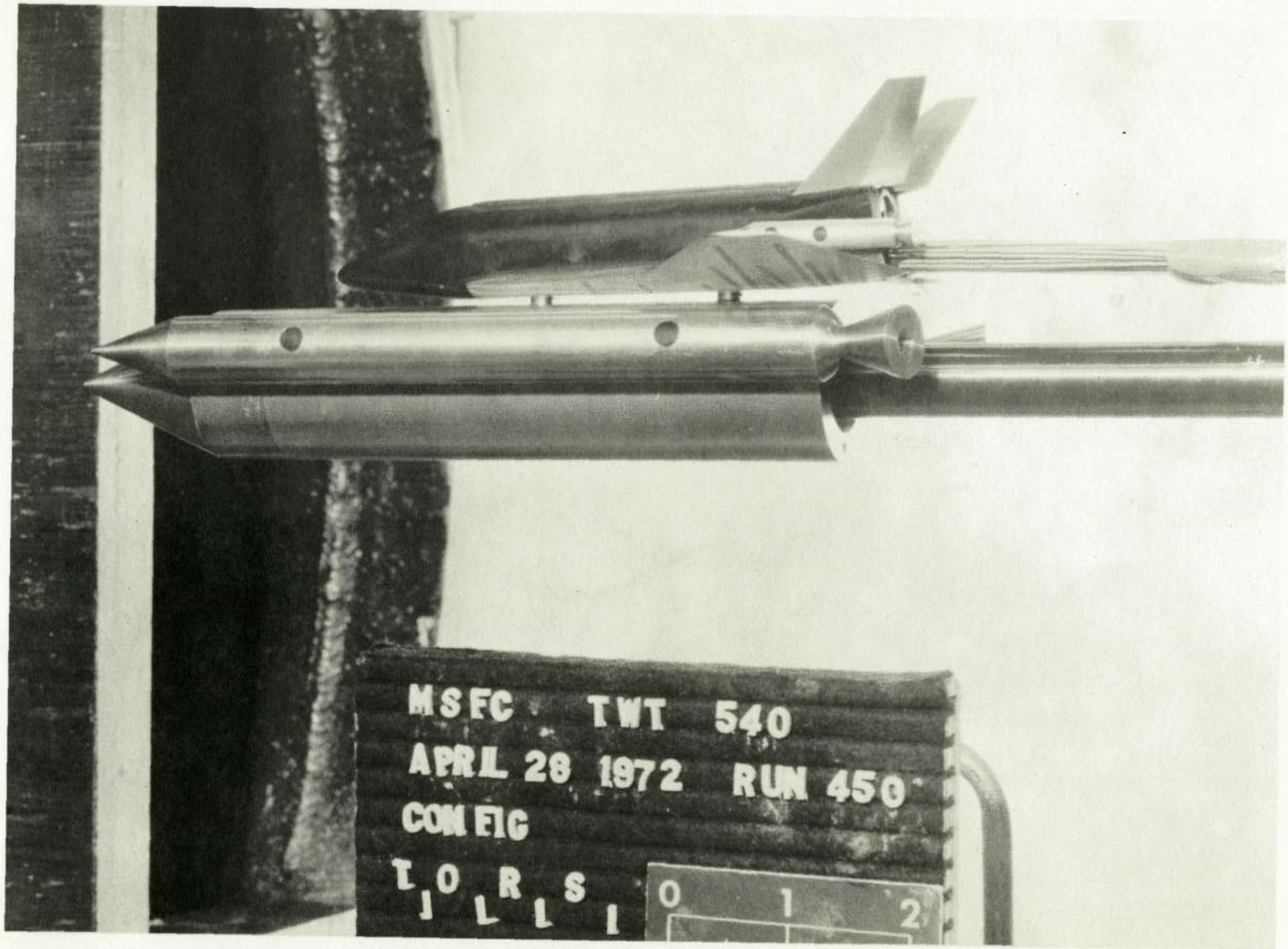


Fig. 27b - Installation Photograph, Orbiter Pressure Test (TWT 550)

2.9 PRESSURE DISTRIBUTION ON 0.004-SCALE HO TANK AND SRMS WHILE MOUNTED IN THE LAUNCH CONFIGURATION (TWT 543)

2.9.1 Test Purpose

Just as local load distributions were needed for the orbiter, local load distributions were also needed for the HO tank and the SRMs. To accomplish this, static pressure taps were located in the HO tank and the SRMs. Test parameters for this study included Mach numbers from 0.6 to 1.96, angles of attack from -10 to 10 degrees and angles of sideslip from -10 to 10 degrees. A pretest report was published in June 1972 for this study (Ref. 12).

2.9.2 Test Facility

The test took place in the MSFC 14 x 14-Inch Trisonic Wind Tunnel. For a description of this facility see Section 2.1.2.

2.9.3 Model Description

The orbiter used for this test is the same as described in Section 2.2.3. The HO tank and SRMs have the same general dimensions as those described in Section 2.7.3. However, to provide for surface static pressure locations, new HO tank and SRMs were constructed of Stycast in which the static pressure orifices were molded. Figures 28 through 30 show the general arrangement of the HO tank and the SRMs and the location of the pressure taps. The sting was permanently molded into the tank, as shown in Fig. 31. The HO tank had 152 pressure orifices and each SRM had 38 orifices for a total of 230 orifices. Figure 32 shows the model as installed in the wind tunnel

The model nomenclature for this test was:

Symbol	Definition
O1	baseline orbiter (including the abort solid rocket motors)
T1	346-in. diam. HO tank with 22-deg nosecone (baseline)
S1	156-in. diam. solid rocket motor with 17-deg nosecone (baseline)

2.9.4 Data Reduction

The local surface static pressures were measured by 50 psid transducers contained in Scanivalves. The static pressures were referenced to tunnel free-stream static pressure and presented in the form of nondimensional pressure coefficients.

The data are currently being incorporated in the Chrysler SADSAC program and will be published as a data report (Ref. 32).

2.9.5 Discussion

The test was run to give a preliminary look at local loads on the HO tank and SRMs while in the launch configuration. The small model scale (0.004) prevented locating as many pressure locations as is usually felt to be desirable on the bodies. This problem was alleviated somewhat by providing three different mounting positions, each spaced 15 degrees radially apart for each SRM. By rotating the SRMs through four positions and then combining the data from both SRMs, pressure distributions at 15-degree intervals could be determined for the entire diameter of an SRM.

Pressure distributions obtained were sufficient for determining load distributions, but more pressure taps would have been necessary to determine local flow singularities such as shock impingement.

The test program is outlined in Table 20. The test program required 132 hours to complete.

Table 20

RUN SCHEDULE FOR TWT 543

DATA SET IDENTIFIER	CONFIGURATION	SCHD. α	SCHD. β	PARAMETERS/VALUES: SRM POS	i_{OE}	Y_{SRM}		NO. of RUNS	MACH NUMBERS (OR ALTERNATE INDEPENDENT VARIABLE): 0.8	0.95	1.10	1.20	1.46	1.96						
	T1	A	0	–	–	–			✓			✓	✓	✓						
	T1Φ1			–	-1.5°	–			✓			✓	✓	✓						
	T1S1			1	–	.025						✓								
				3								✓								
				5								✓								
				6								✓								
	T1Φ1S1 (with abort SRM)			5	-1.5°				✓											
	T2Φ1S1 (without abort SRM)			1					✓	✓		✓	✓	✓						
				3					✓	✓		✓	✓	✓						
		B	0	4						✓		✓								
		A		5					✓	✓		✓	✓	✓						
		A		6					✓	✓		✓	✓	✓						
		0	A	1								✓								
				3								✓								
				5								✓								
				6								✓								
		6		1						✓		✓								
				3						✓		✓								
				5						✓		✓								
				6						✓		✓								

1 7 13 19 25 31 37 43 49 55 61 67 75 76

IDPVAR(1) | IDPVAR(2) | NDV

COEFFICIENTS:

α or β SCHEDULES

α: A = -10°, -4°, 0°, 4°, 10° ; B = ±10°

β: A = -10°, -4°, 0°, 4°, 10°

Table 20 (Concluded)

DATA SET IDENTIFIER	CONFIGURATION	SCHD. α	SCHD. β	PARAMETERS/VALUES SRM POS.	i_{ORB}	Y_{SRM}		NO. of RUNS	MACH NUMBERS (OR ALTERNATE INDEPENDENT VARIABLE) 0.8	0.95	1.10	1.20	1.46	1.96						
	T1Ø1 S1 (without abort SRM)	B	0	5	-1.5°	.05			✓			✓								
	↓	↓	↓	6	↓	.05			✓			✓								
	↓	↓	↓	5	↓	.10			✓			✓		✓						
	↓	↓	↓	6	↓	.10			✓			✓		✓						
	↓	A	0	1	0°	.025						✓	✓							
	↓	↓	↓	3	↓	↓						✓	✓							
	↓	↓	↓	5	↓	↓						✓	✓							
	↓	↓	↓	6	↓	↓						✓	✓							

1 7 13 19 25 31 37 43 49 55 61 67 75 76

COEFFICIENTS: IDPVAR(1) | IDPVAR(2) | NDV

α or β SCHEDULES α: A = -10°, -4°, 0°, 4°, 10° ; B = ±10°

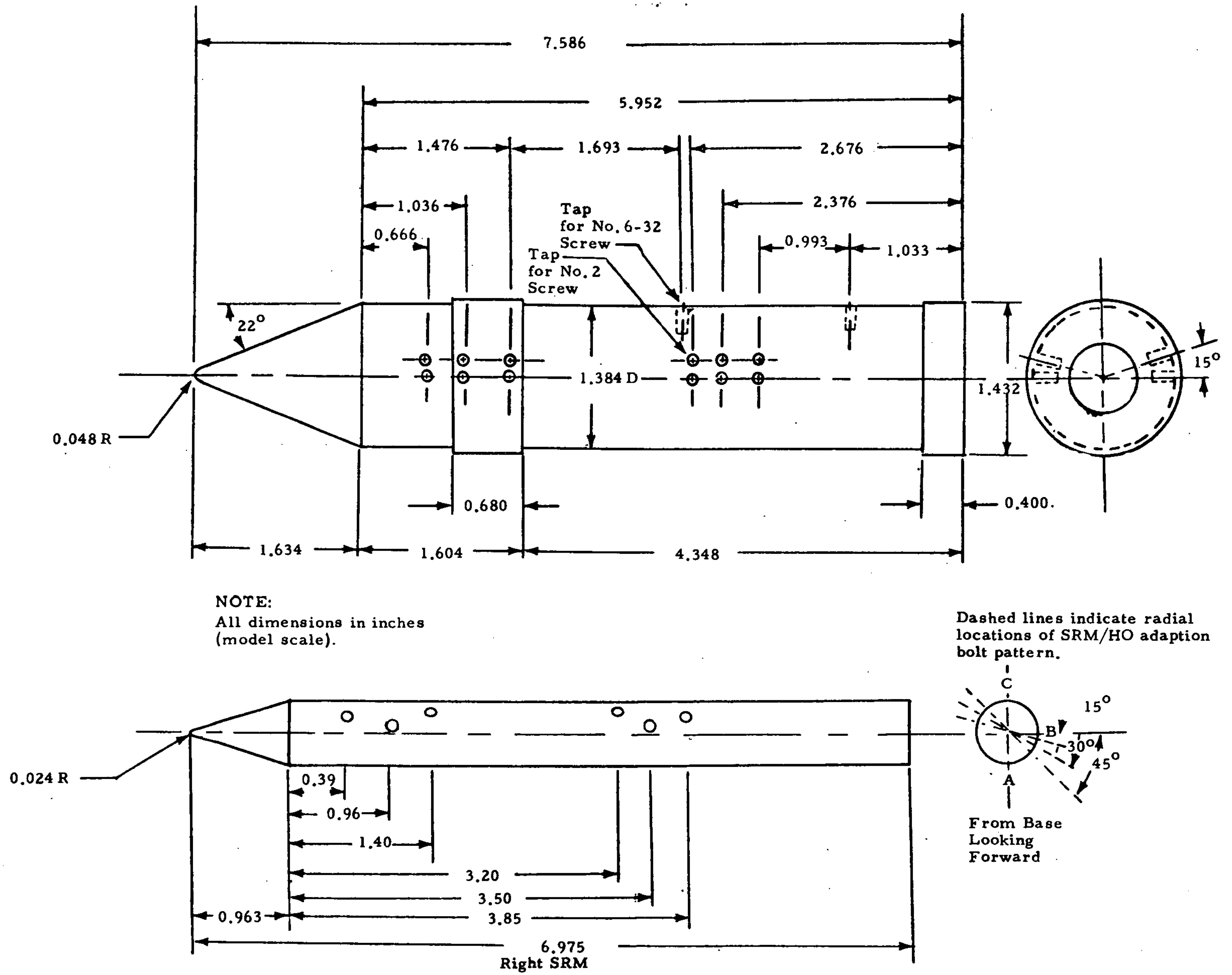


Fig. 28 - General Arrangement for HO Tank-SRM Pressure Test

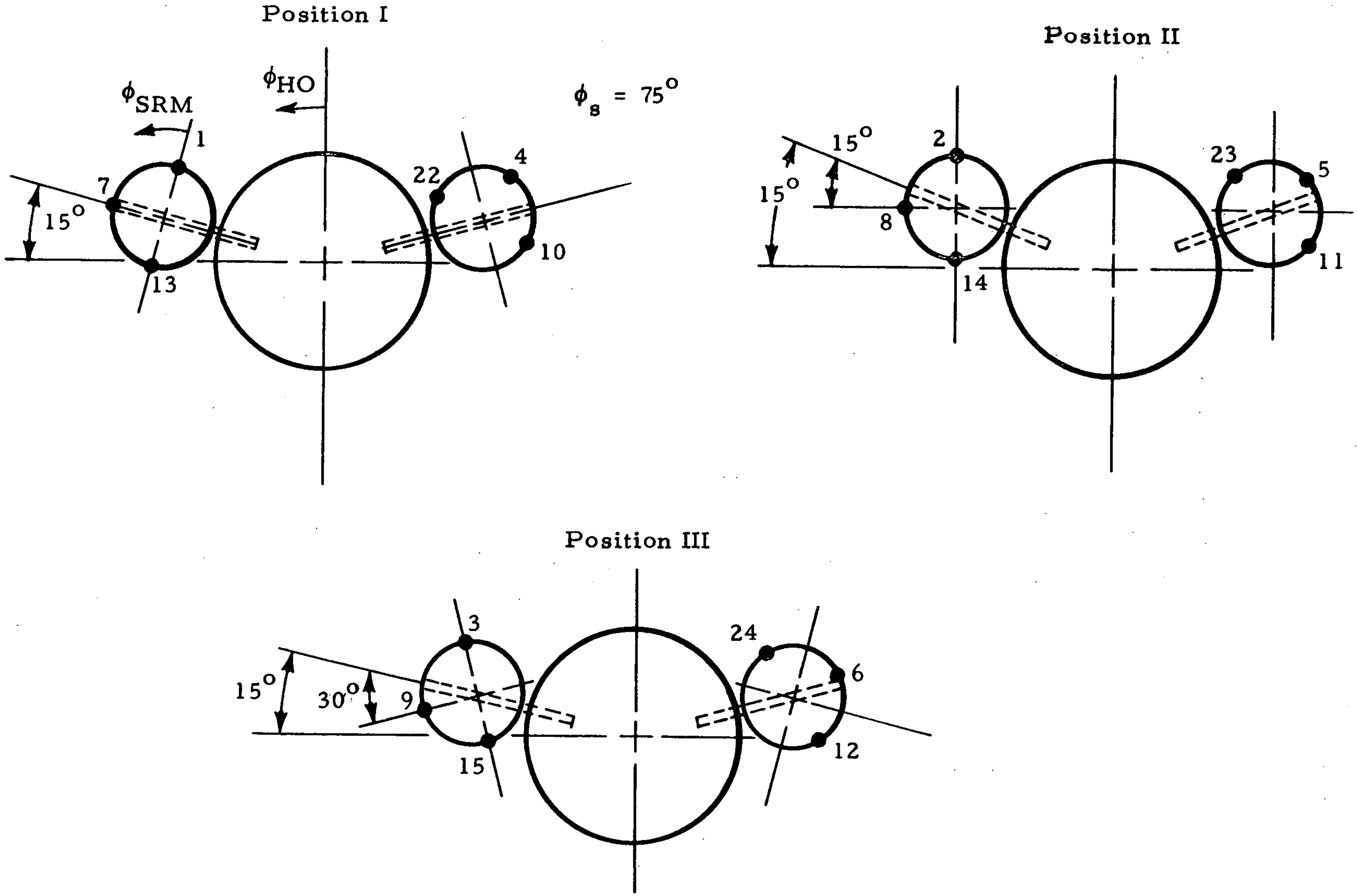


Fig. 29 - SRM Orientations with Respect to the HO Tank for $\phi_s = 75^o$

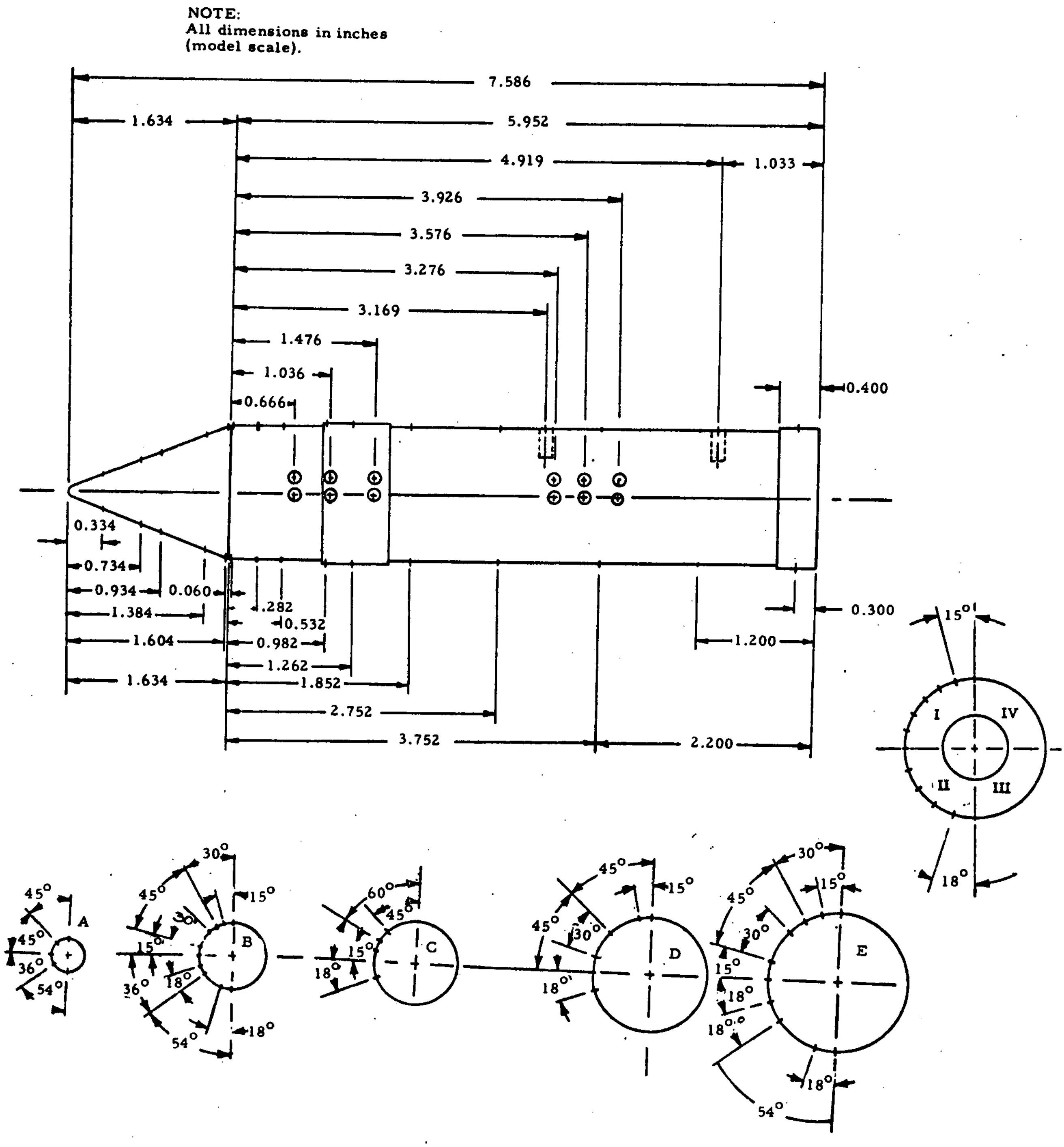
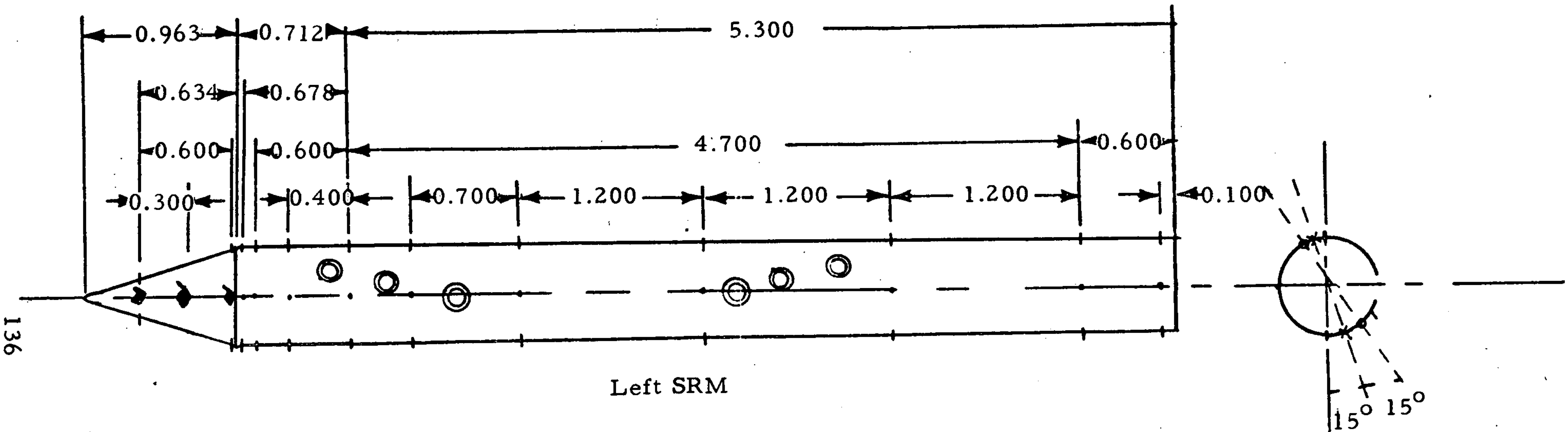


Fig. 30a - HO Tank Pressure Orifice Location

NOTE:
All dimensions in inches
(model scale).



Sym	Tap Location
❘	Top or Bottom
•	Front Side
◆	Back Side
◗	Front and Back

Sym	SRM Positon
❘	I
X	II
○	III

Fig. 30b - SRM Pressure Orifice Location

NOTE:
All dimensions in inches

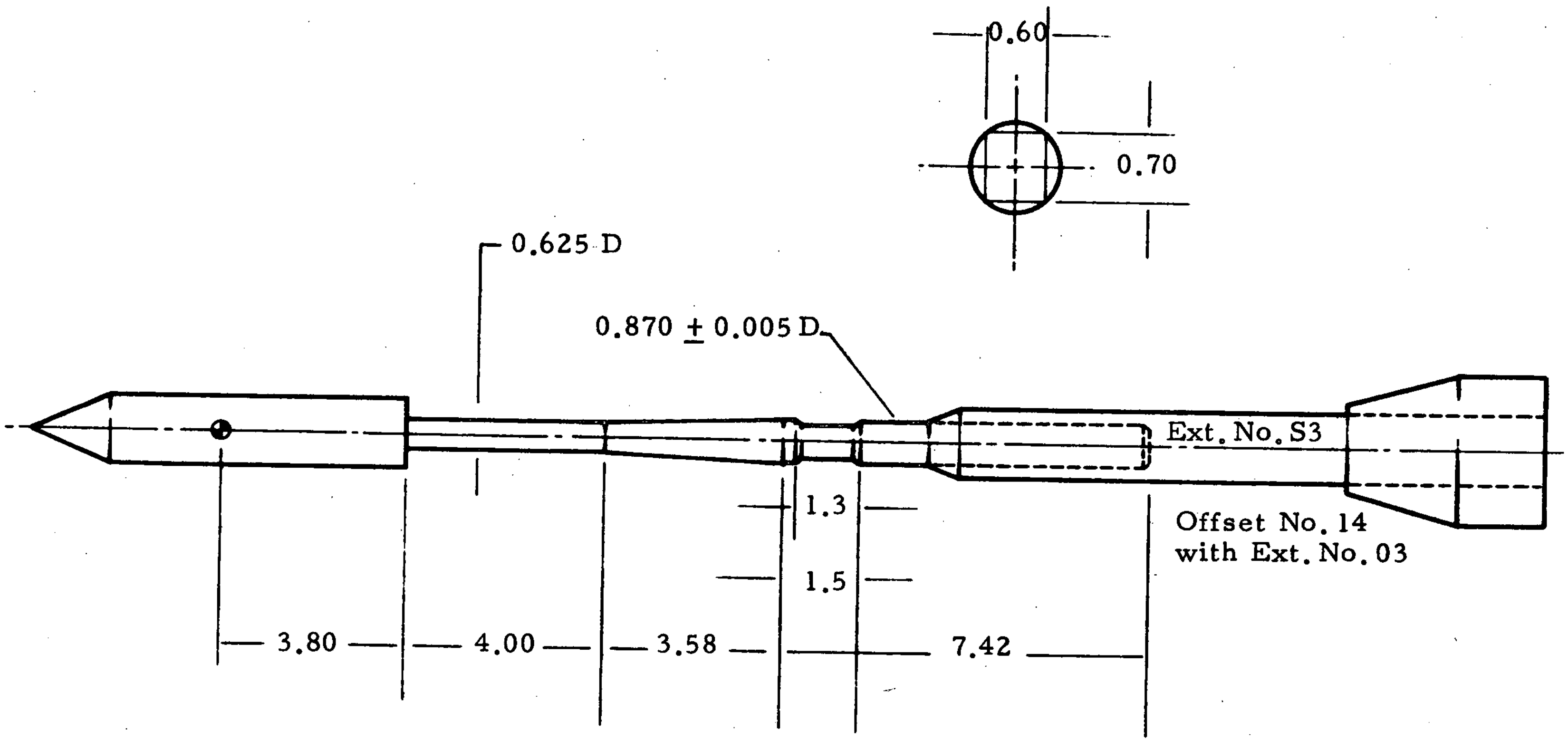


Fig. 31 - Sting Support for HO Tank - SRM Pressure Test

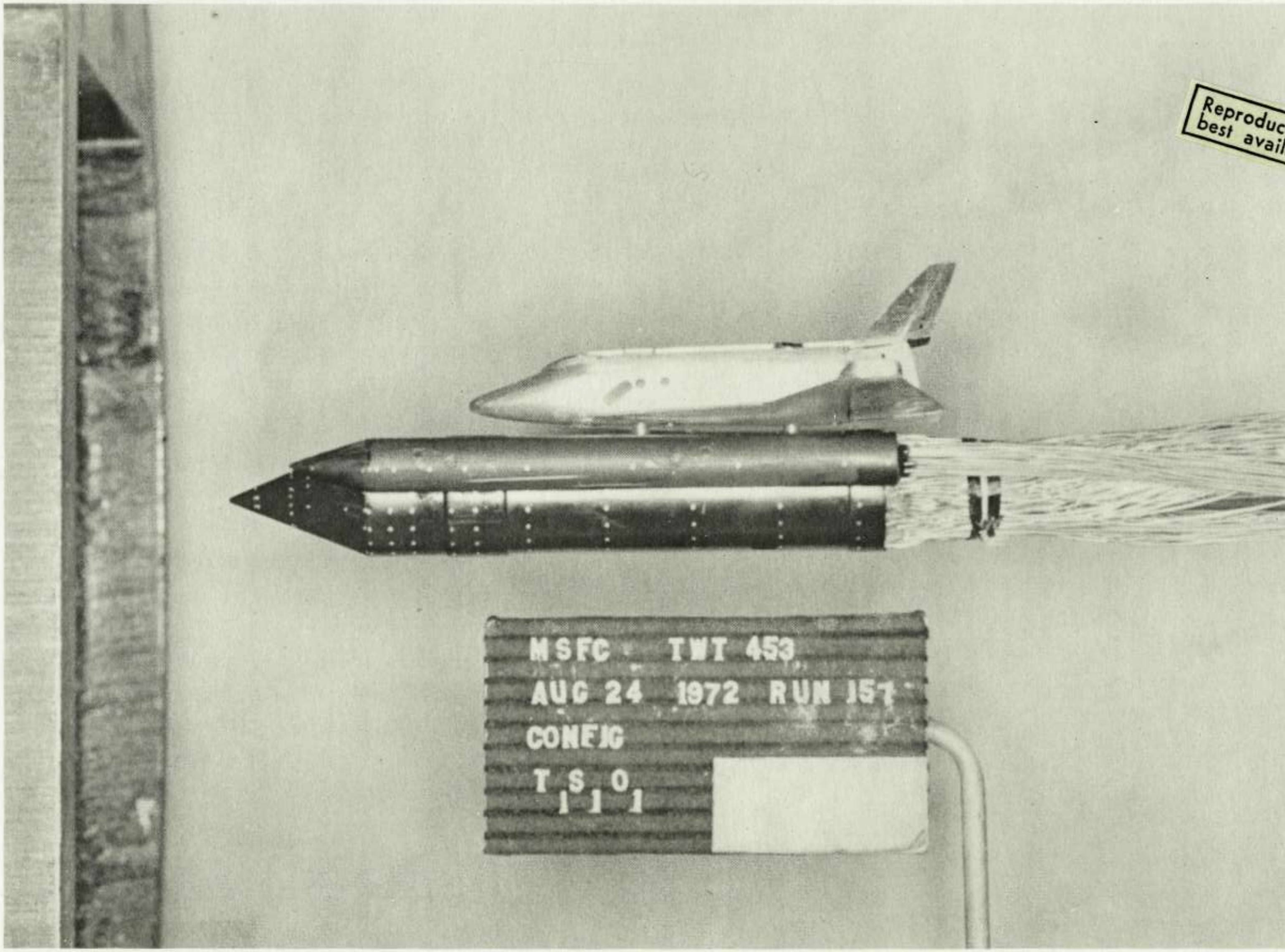


Fig. 32a - Installation Photograph, HO Tank - SRM Pressure Test (TWT 543)

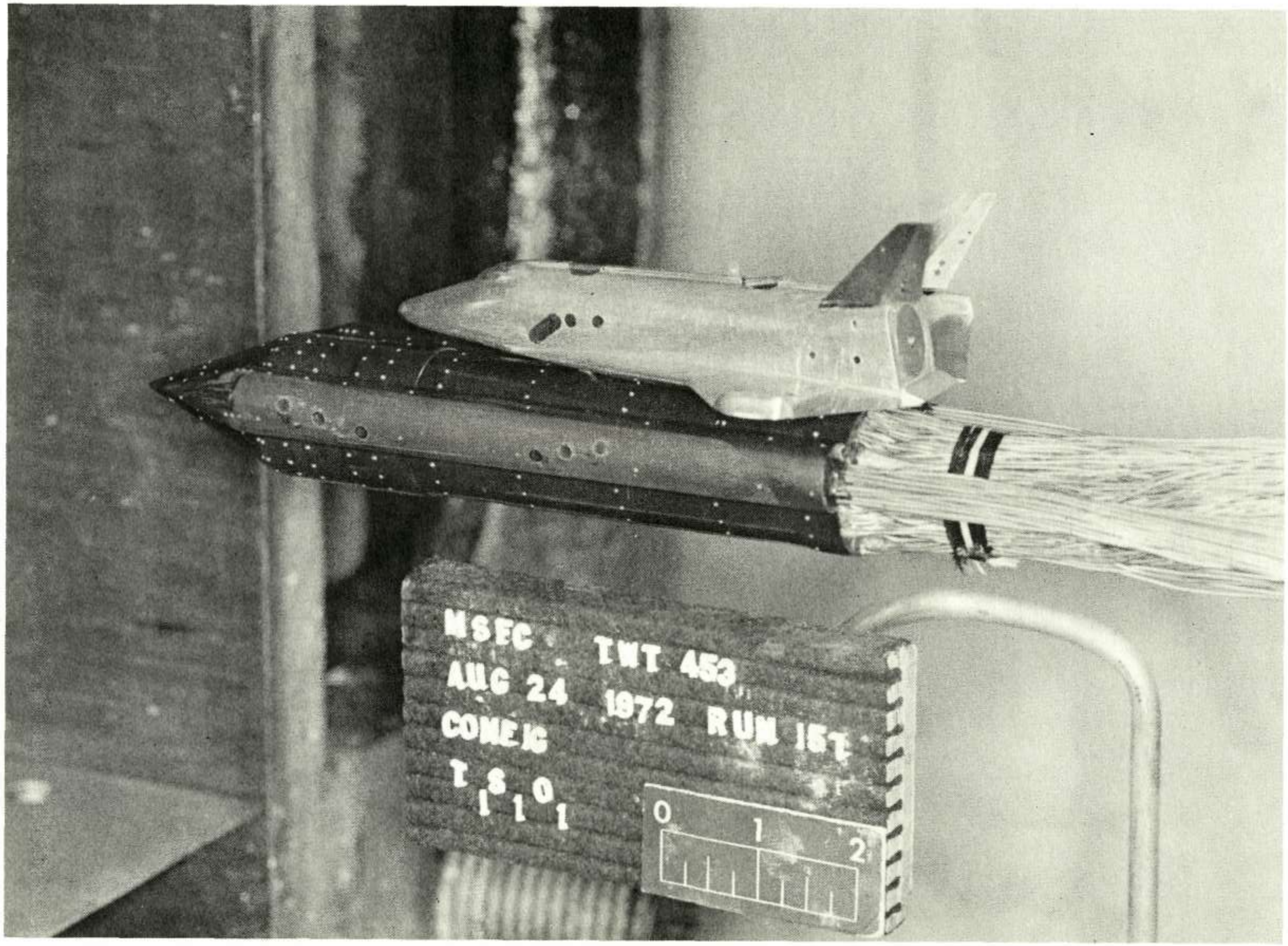


Fig. 32b - Installation Photograph, HO Tank - SRM Pressure Test (TWT 543)

2.10 MUTUAL INTERFERENCE STUDY OF THE ORBITER, HO TANK AND SOLID ROCKET BOOSTER OF A 0.004-SCALE SPACE SHUTTLE LAUNCH CONFIGURATION

2.10.1 Test Purpose

To optimize the space shuttle launch configuration and to size the attachment points of the various components it was necessary to know the individual loads of each component. To determine these loads, the North American Space Shuttle launch configuration was tested on the MSFC Dual-Sting Mounting System. Model parameters included orbiter-to-HO tank incidence angle, orbiter-to-HO tank separation distance, SRB longitudinal position, SRBs attached to the HO tank (metric) and SRBs attached to the lower sting (nonmetric). Test parameters included a Mach number range from 0.6 to 4.96, an angle of attack range from -5 to 10 degrees, and an angle of sideslip range from -6 to 6 degrees at zero degrees angle of attack. A pretest report for this test was published in September 1972 (Ref. 13) and an addendum was published in October 1972 (Ref.14).

2.10.2 Test Facility

The test was conducted in the MSFC 14 x 14-Inch Trisonic Wind Tunnel. For a description of this facility see Section 2.1.2.

2.10.3 Model Description

The orbiter was a 0.004-scale model of the North American Space Shuttle Orbiter. Figure 33 shows a general arrangement of the orbiter. All model parts are made of stainless steel except for the wing and orbital maneuvering system pods which are made of aluminum. The model was designed and constructed at Lockheed-Huntsville.

The 0.004-scale HO tank and booster are shown in Figs. 34 and 35. The tank body, SRB aft body and SRB fins are made of stainless steel. The SRB nozzles are made of brass. All other parts are made of aluminum. The tank and SRBs were designed by MSFC. The model nomenclature for this test was:

Symbol	Definition
O1	baseline orbiter less abort solid rocket booster
T3	318-in. diam. tank with ogive nosecone
S1	156-in. diam. solid rocket motor with 17-deg nosecone and stabilizing fins.

For testing, the orbiter was mounted on the top sting of the MSFC Dual Sting Mounting System. The tank was mounted on the lower sting. Figure 36 shows the mounting system. The SRBs were attached to the tank (metric) or supported by separate stings attached to the lower sting (nonmetric). The SRB nonmetric sting mount is shown in Fig. 37.

Figure 38 shows all components in proximity as for the test. Figure 39a is an installation photograph showing the left SRB mounted in the metric position. Figure 39b is an installation photograph showing the right SRB in the nonmetric position.

2.10.4 Data Reduction

Orbiter forces and moments were measured by MSFC balance 231 and tank forces and moments were measured by MSFC balance 232. The data were corrected for weight tares and reduced to nondimensional coefficients by the use of the reference dimensions shown in Table 21. Initially all data were reduced about the moment reference points of the respective bodies as shown in Table 21.

Since the deflection constants and loads are different for the two bodies, angular and linear displacements are different for the two bodies when pitched through an angle-of-attack sweep. To make consistent comparisons, the bodies must remain in the same relation to each other regardless of configuration.

To nominalize the relative positions of the orbiter and tank, a grid of three incidence angles and two separation distances was tested. After initial data reduction, a Northrop interpolation program (Ref. 33) was used to produce nominalized data at the proper incidence angles and separation distances. The program also transferred orbiter moments to the moment reference point of the tank.

These data are currently being entered into the Chrysler SADSAC program and will be published as a data report (Ref. 34).

2.10.5 Discussion

Data from this test can be used to determine the individual loads of the launch vehicle components. Although the SRBs were not fitted with balances, comparison of the metric and nonmetric SRB data for the tank balance allows an SRB load increment to be computed. Comparison of the load data of a body while in proximity with data obtained for the body while being tested alone will allow computation of the interference loads.

Table 22 is a listing of the configurations tested. The test required 223 hours of wind tunnel occupancy time to complete.

Table 21

NORTH AMERICAN LAUNCH CONFIGURATION REFERENCE DIMENSIONS

Parameter	Full Scale	Model Scale
Reference Area (S_{ref}) (Orbiter Wing Area)	3220 ft^2	7.419 in^2
Reference Length (ℓ_{ref}) (Orbiter Body Length)	1328.0 in.	5.312 in.
Reference Span (b_{ref}) (Orbiter Body Length)	1328.0 in.	5.312 in.
Balance Location		
Orbiter (aft of nose)		3.719 in.
HO-Tank (forward of base)		3.113 in.
Moment Reference Point		
Orbiter		
XMRP (aft of nose)	863.2 in.	3.453 in.
HO Tank		
XMRP (forward of base)	1205 in.	4.820 in.
Base Area (A_b)		
Orbiter	382 ft^2	0.878 in^2
SRB (one)	132.8 ft^2	.306 in^2
HO Tank	553 ft^2	1.271 in^2

Table 22

RUN SCHEDULE FOR TWT 545

DATA SET IDENTIFIER	CONFIGURATION	SCHD. α	SCHD. β	PARAMETERS/VALUES i_{orb}	Z	ϕ_{SRB}	X_{SRB}	NO. of RUNS	MACH NUMBERS (OR ALTERNATE INDEPENDENT VARIABLE) 0.6	0.8	0.9	1.0	1.1	1.2	1.46	1.96	2.99	4.96		
	T3∅1	A	O	0	.12	—	—		✓		✓	✓	✓	✓	✓	✓		✓		
				-1.2					✓		✓	✓	✓	✓	✓	✓		✓		
				1.5					✓		✓	✓	✓	✓	✓	✓		✓		
				0	.24				✓		✓	✓	✓	✓	✓	✓		✓		
				-1.2					✓		✓	✓	✓	✓	✓	✓		✓		
				1.5					✓		✓	✓	✓	✓	✓	✓		✓		
		O	A	0	.12				✓		✓	✓	✓	✓	✓	✓		✓		
	T3∅1S1(metric)	A	O	0		81°24'	0.00		✓	✓	✓	✓	✓	✓	✓	✓	✓	✓		
				-1.2					✓	✓	✓	✓	✓	✓	✓	✓	✓	✓		
				1.5					✓	✓	✓	✓	✓	✓	✓	✓	✓	✓		
				0	.24				✓	✓	✓	✓	✓	✓	✓	✓	✓	✓		
				-1.2					✓	✓	✓	✓	✓	✓	✓	✓	✓	✓		
				1.5					✓	✓	✓	✓	✓	✓	✓	✓	✓	✓		
		O	A	0	.12				✓	✓	✓	✓	✓	✓	✓	✓	✓	✓		
	T3∅1S1(non-metric)	A	O	0					✓	✓	✓	✓	✓	✓	✓	✓	✓	✓		
				-1.2					✓	✓	✓	✓	✓	✓	✓	✓	✓	✓		
				1.5					✓	✓	✓	✓	✓	✓	✓	✓	✓	✓		
				0	.24				✓	✓	✓	✓	✓	✓	✓	✓	✓	✓		
				-1.2					✓	✓	✓	✓	✓	✓	✓	✓	✓	✓		
				1.5					✓	✓	✓	✓	✓	✓	✓	✓	✓	✓		

1 7 13 19 25 31 37 43 49 55 61 67 75 76

COEFFICIENTS: IDPVAR(1) | IDPVAR(2) | NDV

α or β SCHEDULES

α: A = -5°, -4°, -2°, 0°, 2°, 4°, 6°, 8°, 10°

β: A = -6°, -4°, -2°, 0°, 2°, 4°, 6°

Table 22 (Continued)

DATA SET IDENTIFIER	CONFIGURATION	SCHD. α	SCHD. β	i_{orb}	Z	ϕ_{SRB}	X_{SRB}	NO. of RUNS	0.6	0.8	0.9	1.0	1.1	1.2	1.46	1.96	2.99	4.96		
	T3Ø1S1 (non-metric)	O	A	0	.12	81°24'	0.00		✓	✓	✓	✓	✓	✓	✓	✓	✓	✓		
	T3Ø1S1 (metric)	A	O	0			-.624		✓		✓	✓	✓	✓	✓	✓		✓		
				-1.2					✓		✓	✓	✓	✓	✓	✓		✓		
				1.5					✓		✓	✓	✓	✓	✓	✓		✓		
				0	.24				✓		✓	✓	✓	✓	✓	✓		✓		
				-1.2					✓		✓	✓	✓	✓	✓	✓		✓		
				1.5					✓		✓	✓	✓	✓	✓	✓		✓		
		O	A	0	.12				✓		✓	✓	✓	✓	✓	✓		✓		
	T3Ø1S1 (non-metric)	A	O	0					✓		✓	✓	✓	✓	✓	✓		✓		
				-1.2					✓		✓	✓	✓	✓	✓	✓		✓		
				1.5					✓		✓	✓	✓	✓	✓	✓		✓		
				0	.24				✓		✓	✓	✓	✓	✓	✓		✓		
				-1.2					✓		✓	✓	✓	✓	✓	✓		✓		
				1.5					✓		✓	✓	✓	✓	✓	✓		✓		
		O	A	0	.12				✓		✓	✓	✓	✓	✓	✓		✓		
	T3Ø1S1 (left, metric right, non-metric)	A	O	0			0.00		✓		✓	✓	✓	✓	✓	✓		✓		
				-1.2					✓		✓	✓	✓	✓	✓	✓		✓		
				1.5					✓		✓	✓	✓	✓	✓	✓		✓		
				0	.24				✓		✓	✓	✓	✓	✓	✓		✓		
				-1.2	.24				✓		✓	✓	✓	✓	✓	✓		✓		

1 7 13 19 25 31 37 43 49 55 61 67 75 76

COEFFICIENTS: IDPVAR(1) | IDPVAR(2) | NDV

α or β SCHEDULES

α: A = -6°, -4°, -2°, 0°, 2°, 4°, 6°, 8°, 10°

β: A = -6°, -4°, -2°, 0°, 2°, 4°, 6°

Table 22 (Concluded)

DATA SET IDENTIFIER	CONFIGURATION	SCHD. α	SCHD. β	PARAMETERS/VALUES i_{orb}	Z	ϕ_{SRB}	X_{SRB}	NO. of RUNS	0.6	0.8	0.9	1.0	1.1	1.2	1.46	1.96	2.99	4.96		
	T3φ1S1 (left, metric / right, non-metric)	A	0	1.5	.24	81°24′	0.00		✓		✓	✓	✓	✓	✓	✓		✓		
	↓	0	A	0	.12	↓	↓		✓		✓	✓	✓	✓	✓	✓		✓		
	T3S1 (left, metric / right, non-metric)	A	0	—	—				✓		✓	✓	✓	✓	✓	✓		✓		
	↓	0	A	—	—				✓		✓	✓	✓	✓	✓	✓		✓		
	T3S1 (right only, non-metric)	0	A	—	—	↓	↓		✓		✓	✓	✓	✓	✓	✓		✓		

1 7 13 19 25 31 37 43 49 55 61 67 75 76

COEFFICIENTS: → IDPVAR(1) | IDPVAR(2) | NDV

α or β SCHEDULES

α: A = -5°, -4°, -2°, 0°, 2°, 4°, 6°, 8°, 10°

β: A = -6°, -4°, -2°, 0°, 2°, 4°, 6°

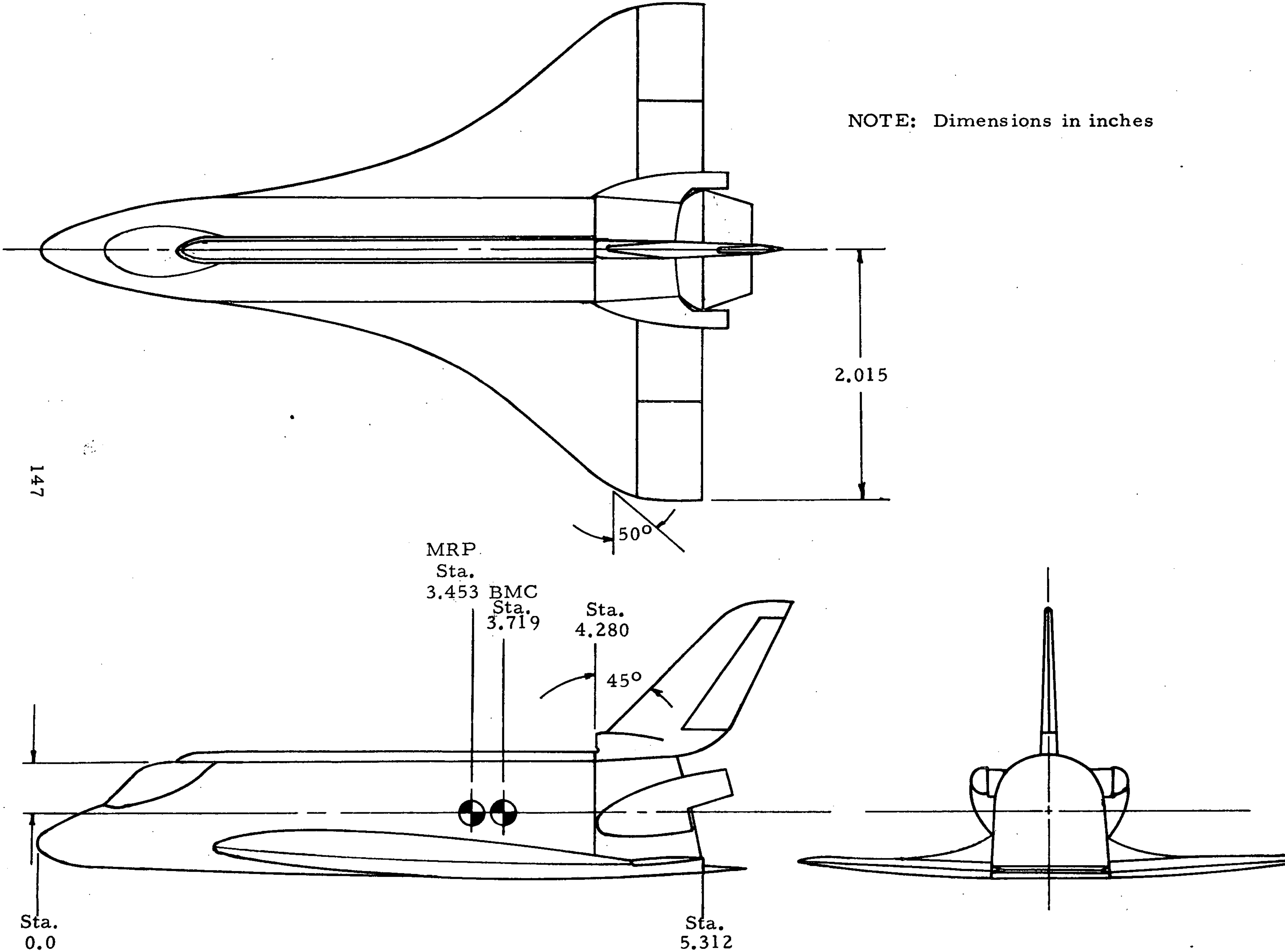


Fig. 33 - General Arrangement, North American Orbiter 01

NOTE: Dimensions in inches

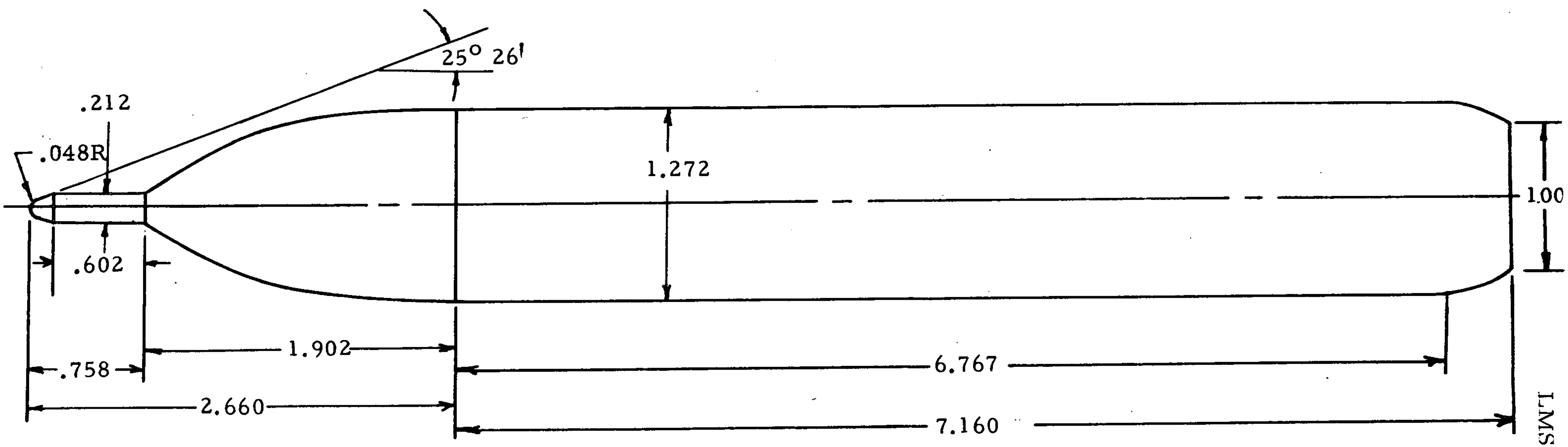


Fig. 34 - General Arrangement, North American External Tank T3

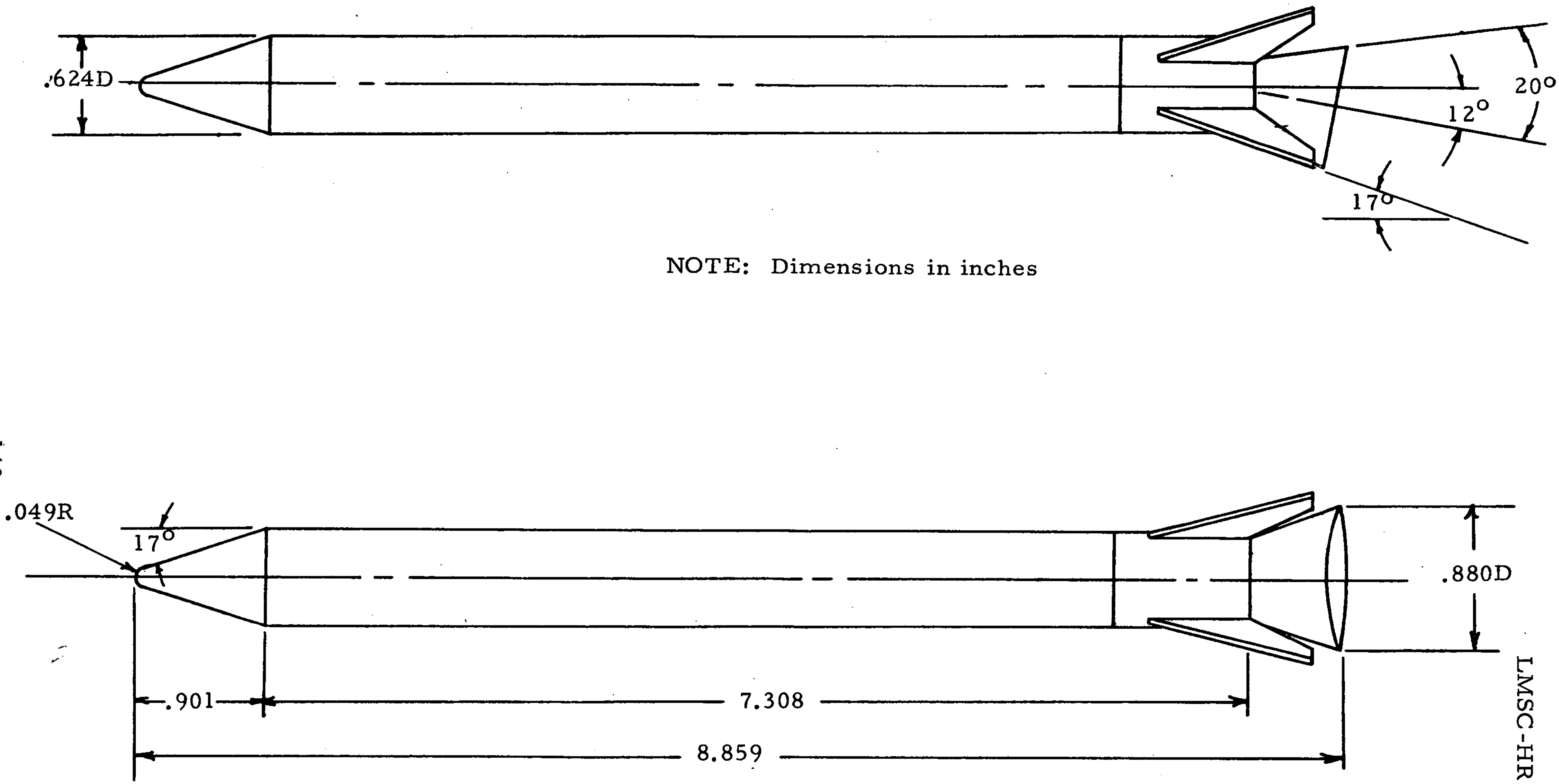


Fig. 35 - General Arrangement, North American SRB S1

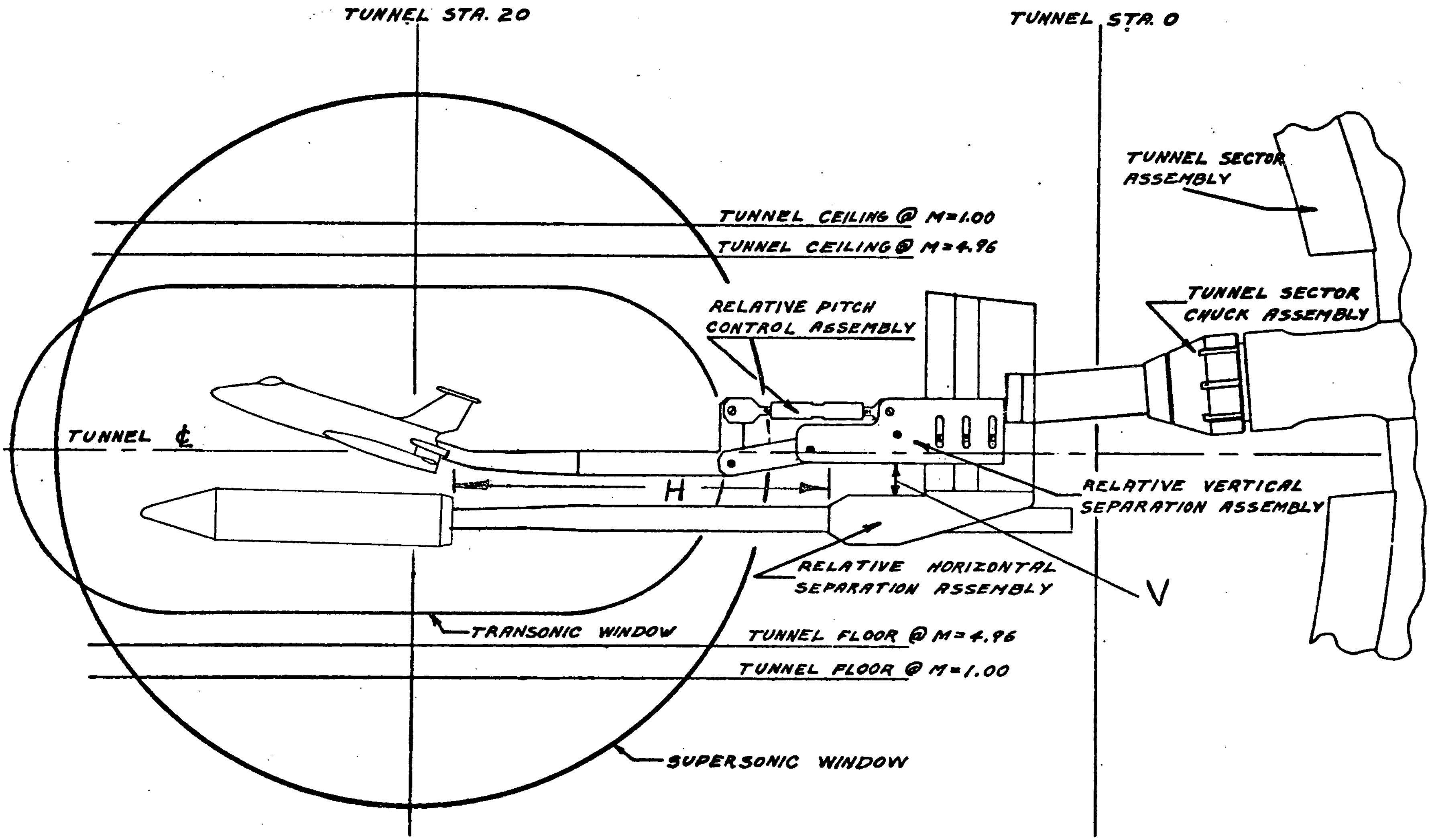


Fig. 36 - Space Shuttle Parallel Staging System for the MSFC 14 x 14-Inch Trisonic Wind Tunnel

NOTE: Dimensions in inches

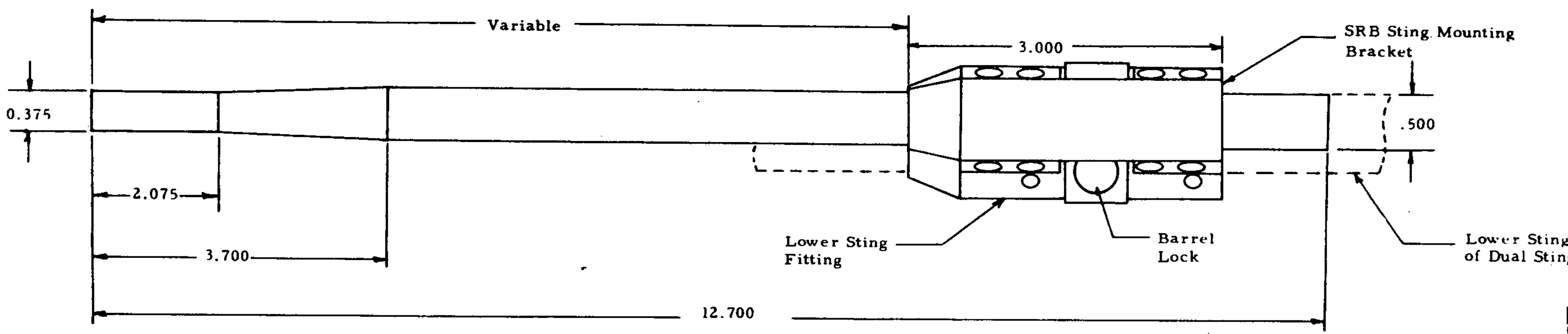


Fig. 37 - SRB Nonmetric Mounting Sting

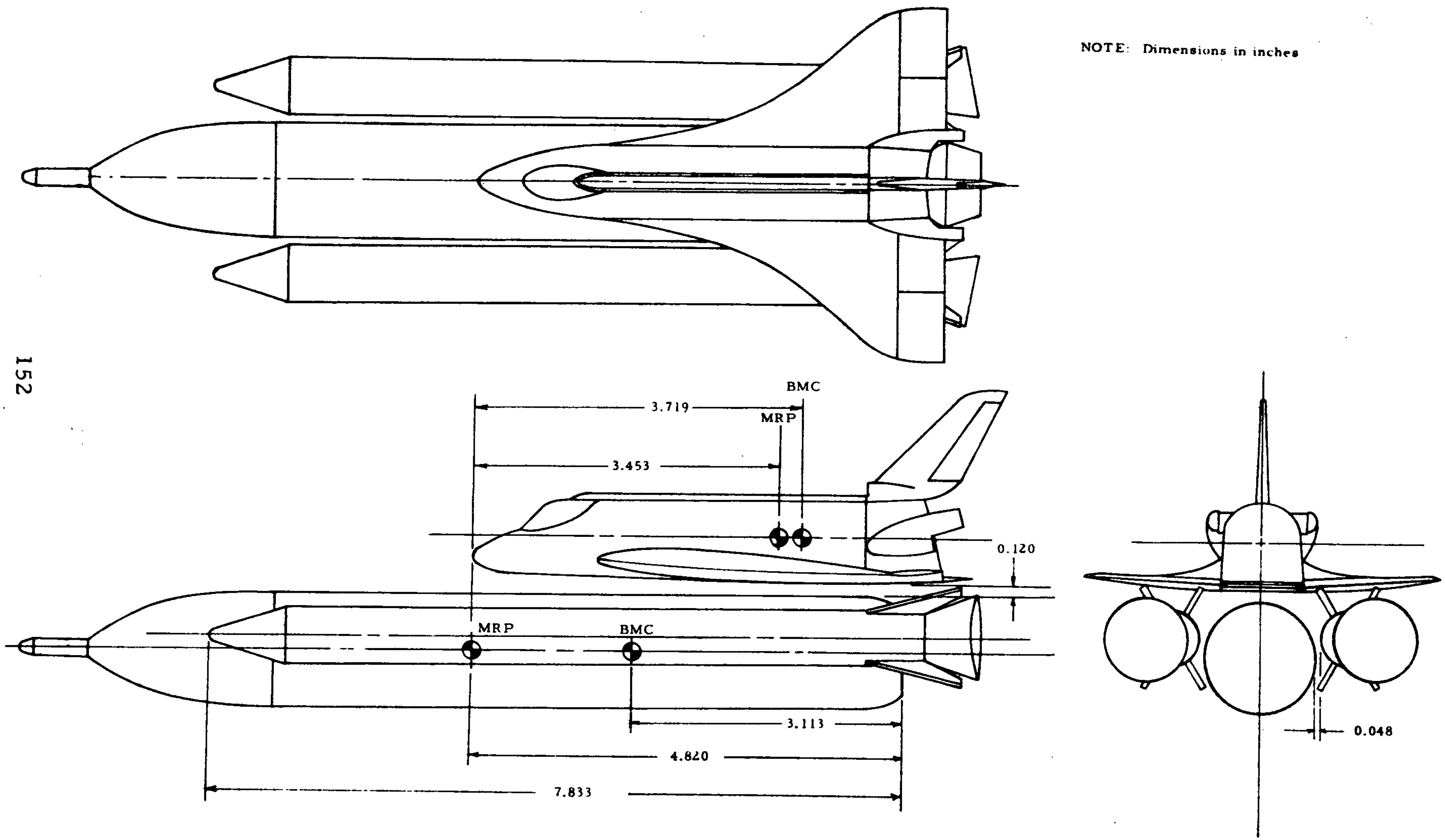


Fig. 38 - General Arrangement, North American Launch Configuration T301 S1

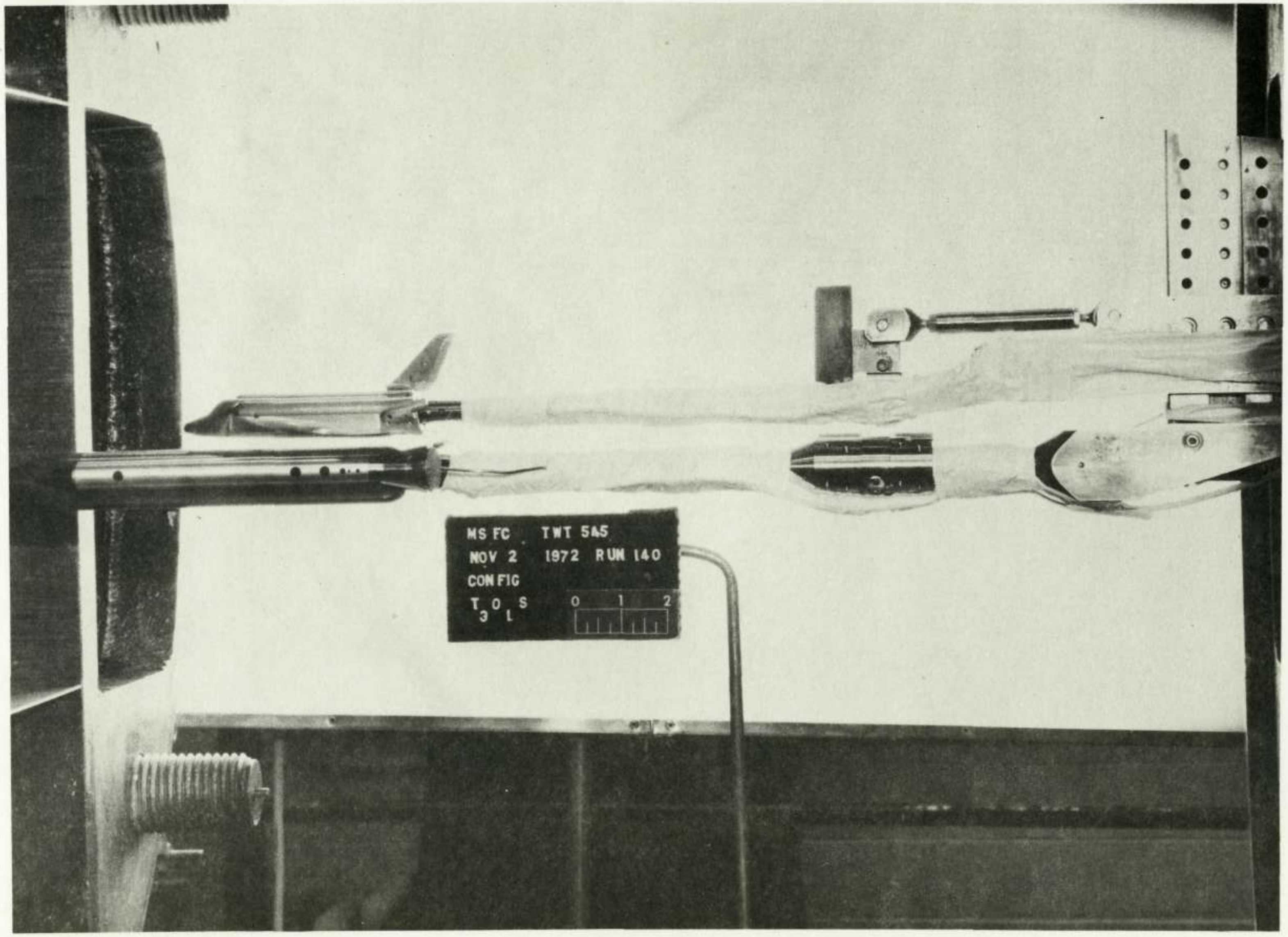


Fig. 39a - Installation Photograph, North American Launch Configuration on Dual Sting (TWT 545)
(Metric SRB)

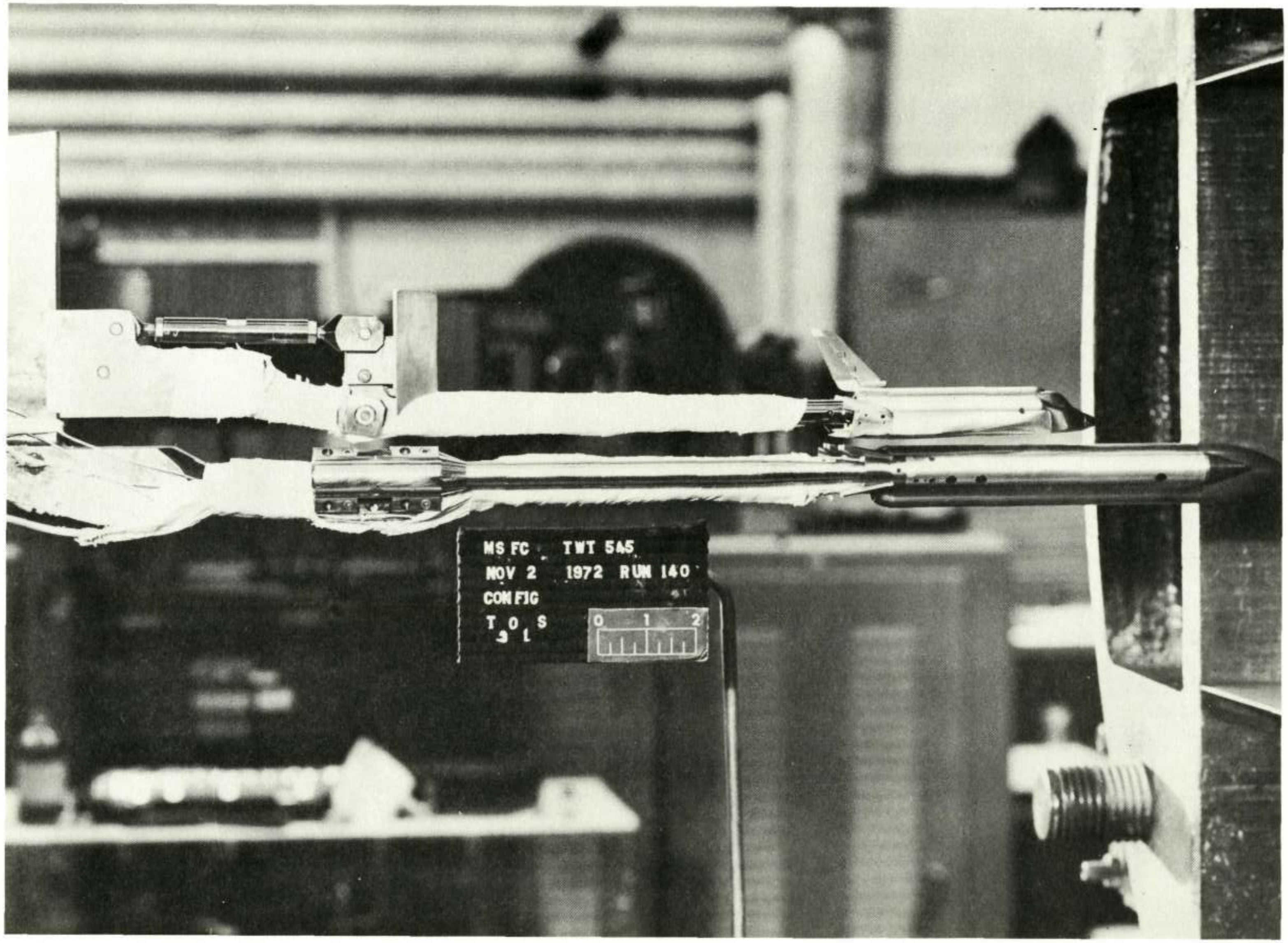


Fig. 39b - Installation Photograph, North American Launch Configuration on Dual Sting (TWT 545) (Nonmetric SRB)

Section 3
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